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The Hubble Space Telescope
faces an uncertain future

Vol. 32 • Issue 11

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Focal Ratio	f/5	f/5	f/5	f/4	f/4	f/4	f/10	f/9	f/9	f/8
Focal Length	762mm	762mm	762mm	812mm	812mm	1016mm	2000mm	1143mm	1143mm	1219mm
Primary Mirror	Plate Glass	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	N/A	N/A	N/A
Viewfinder	6 x 30	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50	8 x 50
Hand Controller	Electronic	Electronic	AutoStar #497	Electronic	AutoStar #497	AutoStar #497	AutoStar #497	Electronic	AutoStar #497	AutoStar #497
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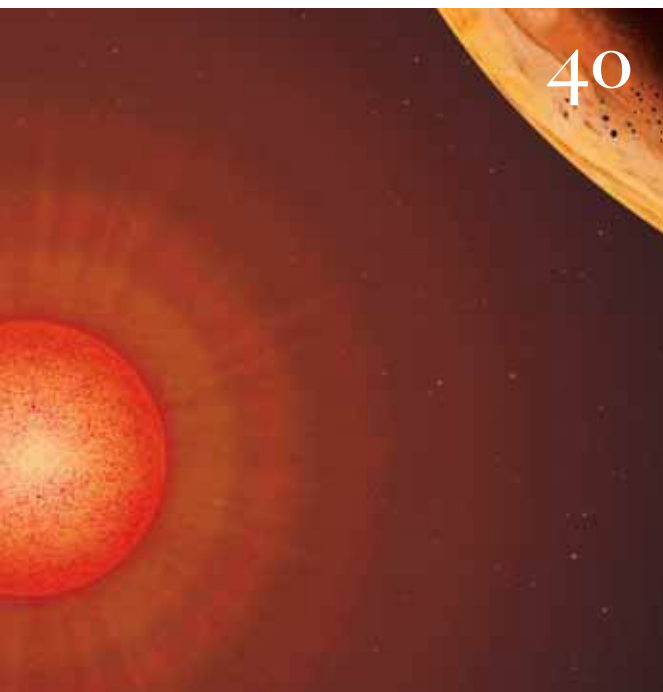
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november 04



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It's been years since our last review of a 2.4-inch refractor, but we found a scope that deserves a report. After reading about Tele Vue's new 60mm refractor, you may decide to add it to your observing arsenal. RAYMOND SHUBINSKI



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ON THE COVER

The Hubble Space Telescope (HST) has given us an unparalleled window into the universe. HST now needs to be refurbished, or it will fail in the next few years. Unwilling to risk a shuttle crew on servicing the telescope, NASA has designed a robotic mission for the job. Yet the robot approach will forestall HST's demise for only about 5 years. NASA

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RED SUN DYING: Some researchers believe Earth will become uninhabitable long before the Sun becomes a red giant. What are our options?

DEATH OF HUBBLE: Has the "culture" at NASA changed since the Columbia accident? Find out what science writer Robert Zimmerman thinks.

CLASSROOM ASTRONOMY: Find out more about Family ASTRO and how you can get involved.

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America loves Hubble

Will NASA abandon the Hubble Space Telescope? After suggesting it would, based on Hubble's need for a space shuttle mission to prolong the telescope's life, the space agency faced a firestorm of criticism. The American public simply didn't want its space-picture machine taken away. NASA Administrator Sean O'Keefe soon turned about

and said his agency would study the possibility of robotic missions to keep Hubble chugging along until a successor is in orbit.

But the clock is running, and no certain plan is in place. Hubble, which has graced the astronomy world with stunning imagery and spectacular findings since its repair 10 years ago, has about 3 years until its batteries and gyroscopes die. The next 6 months will decide whether Hubble is left to expire or is granted a new birth and second life before its career winds down.

Space journalist Robert Zimmerman updates us on the details of what likely will happen — scientifically and politically — in his story, "The looming death of Hubble," on page 46. Two successors of sorts, the James Webb Space Telescope (an infrared instrument) and the Very Large Space Telescope, will come down the pike later. American taxpayers are facing a period when no optical space telescope will be orbiting, capturing cutting-edge views of the cosmos for years.

Closer to home, please help me welcome Dick McNally to *Astronomy's* staff as managing editor. Patricia Lantier, our previous managing editor, left us for the other side of the building to become editor of *BeadStyle* magazine. Pat can pursue her passion in what has become a hobby in her new dream position.

In addition to his position as managing editor of *Astronomy*, Dick is also an editor-at-large for Kalmbach Publishing Co. Prior to moving to *Astronomy*, he was the managing editor of another Kalmbach publication, *FineScale Modeler*. Besides his 6 years



ASTRONOMY MANAGING EDITOR Dick McNally
rejoins the staff. ASTRONOMY: WILLIAM ZUBACK

with Kalmbach, Dick also has served stints with *Airman* magazine, *The American Legion Magazine*, and other publications.

He is a retired Air Force veteran who worked as a reconnaissance precision photo services officer and later flew HH-43F Husky and UH-1F Huey rescue helicopters in Thailand and stateside. He also served as a public affairs officer, managing publications in various global assignments.

Dick has a bachelor's degree in journalism and a master's degree in management. He and his wife, Mary Lee, have three sons. Welcome aboard, Dick.

Yours truly,

Dave Eicher
Editor

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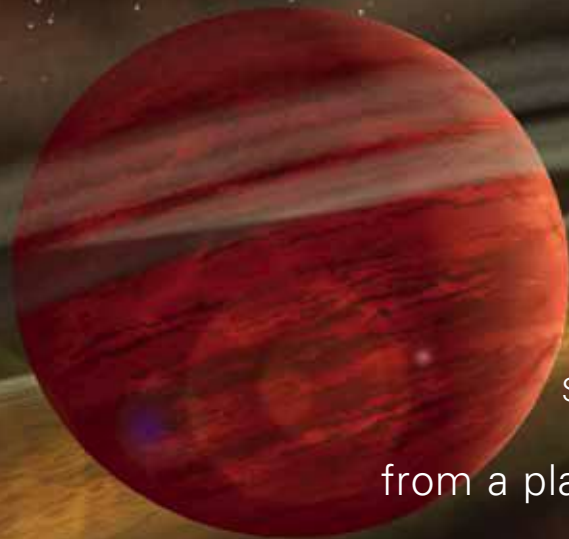
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Mission impossible?

I enjoy every issue of *Astronomy*, and the July 2004 issue was no exception. Robert Pappalardo's article, "Jupiter's water worlds," was impressive, if for nothing more than showcasing our current knowledge of Jupiter's moons. When I was young, my father taught me that Jupiter

has nine moons and Saturn, five. "Wow," I thought — how do they know this? I also remember my 11th-grade science teacher

telling our class we'd never see the other side of the Moon. How just 50 years has changed our knowledge is incredible.

Our technological advancement in space engineering is astounding. Thus, perhaps Pappalardo should not be so certain as to state, "Far beneath its crumbling countenance, the seas of Callisto still stir, but this deep ocean will remain forever inaccessible to humans."

Unless humankind finds a way to annihilate itself first, I don't think anything is impossible. — JACK SWEITZER, MARIETTA, GEORGIA

Cosmological chaos

Kudos to Bob Berman for bringing up the slipperiness of modern cosmology in "Theory chaotic" (July 2004). He must be one of the first to do so. As he makes clear, a healthy skepticism can and should be a necessary part of the scientific method.

— PETE NEWMAN, WESTLAKE VILLAGE, CALIFORNIA

The discovery process

I disagree with Dave Luepke's remarks in "Why not go-to?" (Letters, July 2004). While some people may have an "old-school" mentality, there are more subtle reasons for not encouraging newbies to use go-to telescopes: The thrill of the search and the satisfaction of discovery.

I can't tell you how many times I've looked for a particular object and discovered something else I didn't know was there. A public star party is not the place to make these discoveries. You want to show specific things in a relatively short time, and go-to scopes make this possible.

Far too often, however, I've seen people go through an entire list of objects only to say, "What's next?" They don't really "see" anything, they just notice it on their way to something else. Observing is not a race. It is a slow process of discovery. That child-like excitement of finding an object you've never seen before cannot be matched.

I once asked someone to find a particular object with his scope. He replied, "What number is it?" I told him to point his scope in a particular position, from this star to that. He replied that if it wasn't on his list, he couldn't find it.

The sky is full of wondrous things, but only if we take the time to search them out, really see them and their relationship to the things around them. Why are we so quick to give that away? — SUE ROSE, EAST MEADOW, NEW YORK

Volunteers wanted

Chaco Culture National Historical Park in New Mexico is seeking volunteers to present astronomy programs during summer 2005. A 4- to 6-week commitment is needed. There is limited staff housing, so most volunteers will need to provide their own RVs. Full hookups may be available for volunteers. Also needed are astronomy-minded people to serve as campground hosts. The observatory has a 25-inch Obsession, a 14-inch Celestron, a hydrogen-alpha scope, and a number of smaller instruments. Volunteers are free to use these instruments.

Chaco Canyon is truly an exciting place. Located in northern New Mexico, it is at an elevation of more than 6,000 feet under a great, dark sky. For more information, contact Steve at emil@centurytel.net.

We welcome your comments. Send letters to Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.



BENEATH CALLISTO'S CRUSTY EXTERIOR, a saltwater ocean may flow, but is it accessible? The search for water and life elsewhere in the solar system — and universe — will expand as technology develops. NASA/JPL

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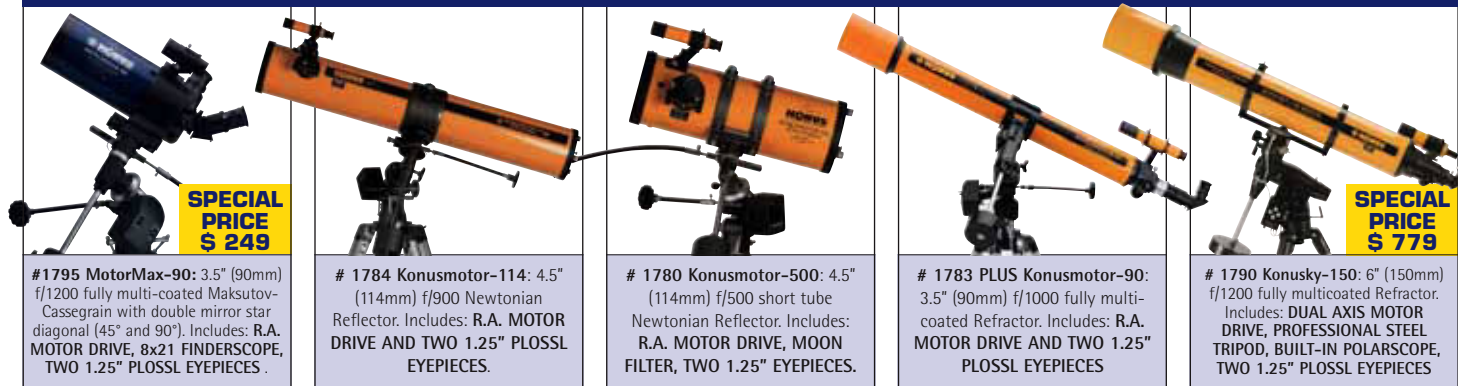


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Glass half empty?

Good news: The wearisome election campaign is ending, finally. The bad news: nearly half the voters will hate the result. ☾ So we take refuge under our beloved starry sky only to find that this “good news-bad news” motif has infected the entire universe. ☾ November, for example, ushers in the 3-month period when nights are

longest. You don't have to wait until after dinner to roll out the scope. The bad news? In most of the country, November also kicks off the year's most overcast season. In much of North America, cloud cover reaches its annual peak percentage then, a dreary situation that lasts until spring.

There's an odd yin-yang quality to our entire planet, so we astronomers shouldn't expect to be exempt. And we haven't been. In 350 B.C. and 200 B.C., respectively, the good news (GN) was that Aristotle and Eratosthenes revealed the shape and size of Earth; but the bad news (BN) was almost nobody believed them.

GN: In 1917, the world's largest telescope, with a 100-inch mirror, is built.

BN: They build it in Los Angeles.

GN: In 1959, for the first time, humans successfully send a spacecraft to the far side of the Moon.

BN: Luna-3 is a Soviet craft, so a zillion new craters get unpronounceable Russian names, permanently.

Historical astro-events follow this double-edged sword theme, too. You know how rare it is to get a total solar eclipse over any big United States city. There are none between 1979 and 2017. But in a 1.5-year span in the 1920s, *two* of the largest

GN: The sci-fi dream of an international space station is realized.

BN: The media and most of the public are bored with it.

GN: We find an extraterrestrial ocean that might harbor life here in our own solar system.

BN: It's on a moon orbiting within Jupiter's fierce radiation belts, so nobody will ever be able to go there.

For a change, let's reverse the order.

BN: In 1915, Einstein blemishes his wonderful general relativity theory by tacking on a cheesy *ad hoc* “cosmological constant.” Later, he slaps his head and calls it his worst blunder.

GN: In 2002, cosmologists decide this “blunder” might be valid after all. Maybe.

It would be nice if this good news-bad news business proves to be just a temporary fashion, like bell bottoms and suspenders were. But theorists' models for planetary and stellar evolution suggest it will go on forever.

The Moon will approach Earth until tidal forces break our nearest neighbor into a trillion pieces, forming a glorious ring to rival Saturn's.

GN: In 140 B.C., Claudius Ptolemy figures out the distance to the Moon.

BN: He sets back science for the next 1,500 years with his wacky Earth-centered scheme and obsession with astrology.

GN: In A.D. 1610, Galileo, while observing Jupiter's moons, proves that Earth isn't the center of all motion.

BN: Priests looking through his telescope insist they can't see a thing.

GN: In the 16th century, explorers sailing under far southern skies discover myriad new stars.

BN: They saddle their new constellations with bizarre names like “The Fly” and the “The Air Pump.”

cities were scheduled for totality. Many universities could afford only one research expedition, so they had to choose. Which had the best shot at clear weather: L.A. in fall, or New York in winter? A no-brainer, right? Almost everyone went to southern California with its fabled blue skies. The bad news was that La-La land was leaden September 10, 1923, while the Big Apple was cloudless January 24, 1925.

The theme continues to modern times.

GN: A fleet of reusable space shuttles is created that can carry up to seven astronauts into orbit.

BN: Two separate in-flight disasters leave the fleet grounded for years at a time.

Someday, the Moon will stop its current inch-a-year departure from us and reverse direction. It will approach Earth until tidal forces break our nearest neighbor into a trillion pieces, forming a glorious ring to rival Saturn's. Will future humans — evolved to where they *lack* toes but *can* wiggle their ears — regard that as good news? Or, will it be bad news for clammers (tides will fall to three-eighths of what they are now) and astronomers?

This whole topic is getting played out.

BN: Inertia makes it hard to stop, and the writer doesn't seem to know when enough is enough.

GN: We're out of room. ■



Cassiopeia delights

A few months ago, I explored some deep-sky sights in Cassiopeia with my 4-inch Dobsonian-mounted reflector. Immersed in the Milky Way, Cassiopeia is profuse with telescopic wonders — especially double stars and open star clusters. Armed with a star atlas and finder charts, I worked my way from one end of Cassiopeia to the

other, concentrating on anything accessible to a beginner using a small-aperture telescope. Try your luck with the following, using the map on this page to help you find your way around Cassiopeiae.

Alpha (α) Cassiopeiae: a wide, unequally bright optical double star. The companion (magnitude 9.0) is 400 times fainter than the yellowish magnitude 2.5 primary, but it's easily seen with magnifications as low as 25x.

Eta (ε) Cassiopeiae: a colorful yellow and red duo (magnitudes 3.4 and 7.5, separation 13"), situated a few degrees northwest of Alpha Cas. It's a fine sight at 100x.

Iota (ι) Cassiopeiae: a triple star whose magnitude 4.6 primary is accompanied by stars of magnitudes 6.9 and 8.4 at distances of 2.5" and 7.2", respectively. The magni-

tude 6.9 companion may be hard to see in small scopes. Try 100x or more.

M52: a rich, condensed open star cluster whose approximate location is found by tracing a line from Alpha through Beta (β) Cassiopeiae, and extending it an equal distance beyond. Look for a sprinkle of stars surrounded by the nebulous glow of unresolved cluster members. My best view was with 100x.

M103: a small, somewhat sparse cluster located just a degree from Delta (δ) Cassiopeiae. The surrounding area contains a number of clusters, including NGC 663 and NGC 654. NGC 663 is a rich oval-shaped group that, to me, is more visually attractive than M103. NGC 654 appears as a small, faint glow, and 100x works best to capture a good view of this cluster.

Also in the field is Trumpler 1 (a.k.a. the "Zipper Cluster"). This neat little star group was shown to me by Amherst, Massachusetts, amateur John Davis at the Astronomer's Conjunction in Northfield, Massachusetts, a few summers ago.

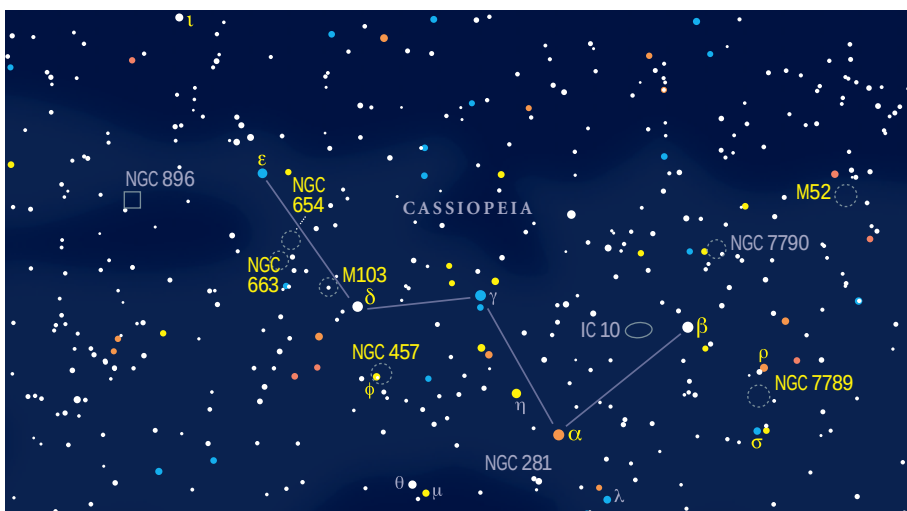
In July, I discussed the value of astronomy conventions ("Astro-socializing," July 2004). Getting to tap the knowledge bank of veteran observers like John is one reason I attend these gatherings. If you are at Stellafane in Springfield, Vermont; the Astronomer's Conjunction; or Arunah Hill Days in Cummington, Massachusetts, next year, look for John Davis and ask him to show you the "Zipper Cluster."

NGC 7789: a large, rich cluster found midway between Rho (ρ) and Sigma (σ) Cassiopeiae. This cluster appears as a ghostly glow sprinkled with fine stardust. Use low power.

NGC 457: neat cluster! Some observers liken its appearance to an owl, with the bright, wide double star Phi (φ) Cassiopeiae forming the glowing eyes and outwardly branching rows of stars creating the wings, body, and tail. I saw an alien, with the owl's wings looking more like spindly arms. What do you see?

In August, I wrote that M57 (the Ring Nebula) appears annular "only through 6-inch scopes or larger" ("A ring and a triangle," August 2004). This prompted an e-mail from Arizona amateur Bill Delinges, who noted he has seen the "ring" with both a 4-inch reflector and 100mm binoculars. When I describe the appearance of a sky object, I consider its visibility to the eyes of the typical reader of this column — a novice, using ordinary equipment, under average sky conditions. For such an individual, seeing the "ring" with a telescope smaller than 6 inches in aperture would be difficult, if not impossible. Bill, I'd love to skygaze from your Arizona skies!

Next month: some holiday gift ideas. Clear Skies. ■



CASSIOPEIA HOUSES many dazzling objects. Orient yourself by facing north. Tilt your head back so south is at the top of your view. Cassiopeia will be just about overhead. ASTRONOMY: ROEN KELLY

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Solar Image by-Bastien Confino, Gregory Giulianiand, and Patrick Chevalley- Switzerland- taken with the P.S.T.



Anthony Aveni

Equal parts classically trained

astronomer and Indiana Jones, with a sprinkle of Nutty Professor added, Anthony Aveni puts a refreshing spin on the station of science in cultures come and gone. Nearly 4 decades after he helped create the multidisciplinary effort we now know as archaeoastronomy, Aveni continues to sift

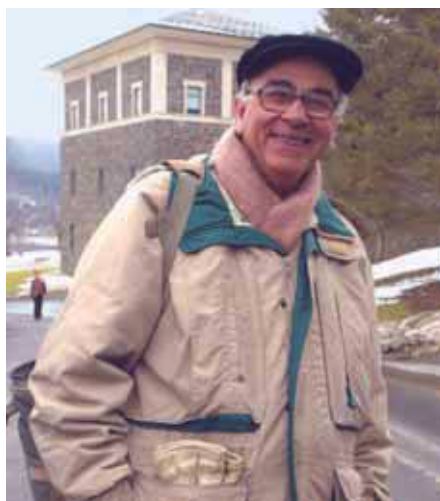
through the indigenous artifacts of the world in search of clues about what the cosmos meant to our ancestors. Aveni has edited and authored more than two dozen books on astronomy and ancient cultures. As the Russell B. Colgate Professor of Astronomy and Anthropology at Colgate University, he studies such enduring and ancient mysteries as the Nasca lines of Peru, the star of Bethlehem, and the astronomical alignments of Mayan pyramids.

What does it take to be a successful archaeoastronomer?

Being a successful archaeoastronomer has a lot to do with developing an attitude about culture. It's not just simply about discovering astronomical alignments in ancient architecture and environments. It's about understanding the culture, and that means understanding something about who wanted this astronomical knowledge, why they wanted it, and what they did with it. Astronomers today tend only to want to know: Did they observe the Sun? Did they observe the Moon? Could they predict eclipses? Archaeoastronomy is really closer to cultural anthropology than to science.

But you entered the field as a scientist. How has your outlook evolved throughout the years?

When I started with archaeoastronomy 35 years ago, I was much more scientific minded and I thought about astronomical-aligned buildings as observatories where



ANTHONY AVENI may not wear a fedora or carry a whip, but his archaeoastronomy adventures rival those of Indiana Jones. JOHN HUBBARD

specialized astronomers would go to practice their craft. Now, as I understand more about ancient cultures, I realize that it's probably the ritual aspect of these buildings that's more important, so that they were probably more like planetariums than observatories. That is to say that they were theaters. Not theaters for entertainment, but theaters in which one tries to set the stage for the coming of the sky gods, so that when they appear, then we can conduct our rituals and we can pay our debt to the gods and we can know and be sure that the world won't be destroyed.

And that's one of the most fascinating things about practically all of these cultures we study save for our own — that the astronomy is driven by religion.

Which of the ancient cultures fascinates you most?

The Maya of Yucatan have always intrigued me, and I've often asked myself why. I think it's because they did things much like we do them. They had a complex system of writing and mathematics. And they were reductionists, just like us. They believed the behavior of nature could be reduced to a minimum set of mathematical laws.

Of course, they were also watching the sky very carefully. They were timing the movement of Venus very accurately, and they were predicting eclipses. So, like no other ancient culture on this side of the Atlantic, they were quite involved and adept with astronomy.

What's the greatest unsolved mystery of archaeoastronomy?

When we encounter ancient alignments or tables documenting how the planets were moving, or how the Sun was rising, or where eclipses were occurring, the astronomers' notebooks are almost always missing. We find some original documents painted on bark paper or on tanned animal hide, for example, but it's always the finished product. I'd really like to find astronomers' personal diaries and notebooks to get a better understanding about how these ancient astronomies came together. To use the carpenter's analogy, I'm not interested in finding the finished chair or the finely carved and polished desk. I want to see the discarded sticks — the mistakes, the ruled pencil lines underneath the paint and the varnish.

There's one famous such notebook, which I've written about in my book *Conversing with the Planets*, that came from Babylonia. The astronomer is writing to himself, "Dear God, please let me be correct about this prediction, or the King will have my head for it." ■

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news II

Read all about it: showers of asteroids striking Earth, the wanderings of a Moon rock, a new kind of spherule in Mars dirt, the violent past of NGC 5128, and new moons for Saturn and Neptune.

EXTRASOLAR PLANETS

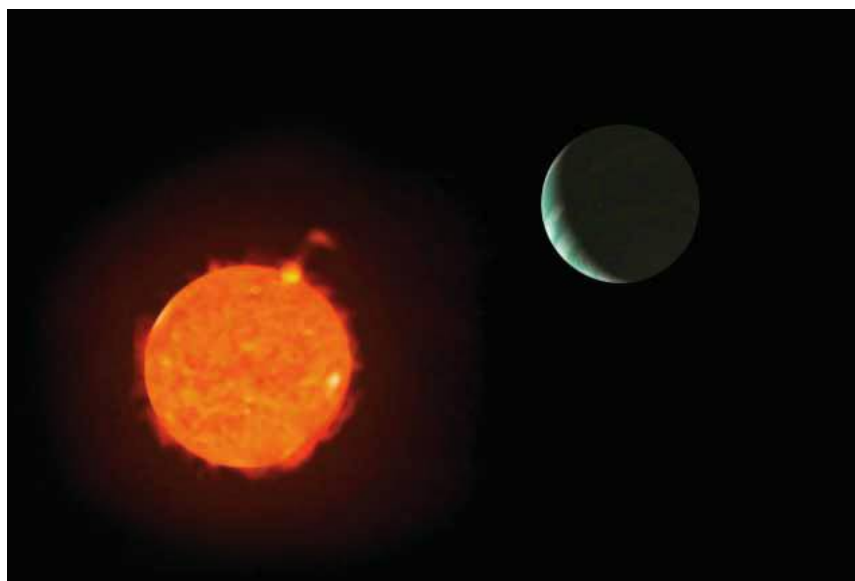
Exo-Neptunes found

Three new extrasolar planets with the smallest masses known have been discovered by astronomers. All three orbit different stars and have masses similar to Uranus or Neptune. The discoveries show exoplanet searches have made a major advance in the quest to find “other Earths,” exoplanets that resemble our own.

One team, led by Paul Butler (Carnegie Institution of Washington), used the 10-meter Keck 1 telescope to discover a periodic wobble in the radial velocity of a small, cool M-type star, Gliese 436, which lies 33 light-years distant. The wobble repeats every 2.64 days, indicating a planet with a mass of roughly 25 Earths. It orbits just 0.028 astronomical unit (AU) from the star.

One astronomer on Butler’s team, Debra Fischer (University of California, Berkeley), had been studying the Sun-like star 55 Cancri, already known to have three planets. She found a residual wobble in the star’s radial velocity that could not be accounted for by the three known planets. Suspecting a fourth planet in the system, she collaborated with Barbara McArthur (University of Texas), who took more spectra of the star with the 9.2-meter Hobby Eberly Telescope. These observations revealed a fourth planet with a mass of about 18 Earths orbiting with a period of 2.81 days at a distance of 0.038 AU. The star lies 41 light-years away and is the first known exoplanet system with four members.

The third “new Neptune” was announced by a team led by Michel Mayor (Geneva Observatory, Switzerland) that used the 3.6-meter telescope at the European Southern Observatory. This new planet appears to have about 14 Earth-masses and orbits the star Mu (μ) Arae, which lies



THREE NEW “NEPTUNES” have been found orbiting stars within 50 light-years of the Sun. The new planets are smaller than any exoplanets discovered before. NASA/JPL

50 light-years away. It orbits only 0.09 AU from the star and has a 9.6-day “year.”

None of these new worlds is habitable to us. The Gliese 436 planet has a sunnyside temperature of about 700° Fahrenheit (650 kelvins), while the new 55 Cancri planet is hotter still: 2,200° F (1,500 K). The Swiss team’s planet falls between the two, being about 1,100° F (900 K).

Whether the new Neptune-mass bodies are miniature Jupiters (“gas midgets”) or scaled-up terrestrial planets (“super Earths”) is unresolved. Uranus and Neptune combine rock and ice and thus form a bridge between the two dominant planet types within our solar system.

“We’re poised for the next step — finding true Earth-size planets,” says Geoff Marcy (U. C., Berkeley), from Butler’s team. —ROBERT BURNHAM



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No Purchase Necessary. The official start date for the Astronomy Winter 2004 Sweepstakes is September 24, 2004. Official entry forms are bound in the November, December 2004 and January 2005 issues of Astronomy. The Astronomy Winter 2004 Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and sent it to: Astronomy Winter 2004 Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the Astronomy Winter 2004 Sweepstakes is January 7, 2005, and all entries must be transmitted or postmarked no later than that date.

Prizes and Odds of Winning. One drawing will be held on or about January 31, 2005, for the following awards: One Grand Prize consisting of a 14" LX200™ GPS Telescope with Smart Mount™ (retail value \$5,345.00). One First Prize consisting of an 8" LX90 Telescope with UHTC™ (retail value \$1,870.00). One Second Prize consisting of a LXD75™ SN-8AT Telescope (retail value \$1,074.00). Three Third Prize consisting of Deep Sky Imager™ with Autostar Suite™ (retail value \$299.99). Three Fourth Prizes consisting of Nightview™ (retail value \$299.00). Cash equivalents of merchandise will not be awarded. Substituting

prizes is not allowed. Any applicable federal, state and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for Astronomy Magazine is 145,473. Sweepstakes void in Quebec and void where prohibited.

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PLANETARY SCIENCE

Asteroid showers?

Two craters 35 million years old are raising the idea of “showers” of asteroids. Roald Tagle (Natural History Museum, Berlin) and Philippe Claeys (Vrije Universiteit Brussel) studied two terrestrial craters: Popigai in Siberia and one called Chesapeake Bay, off the Virginia coast.

Writing in *Science* (July 23, 2004), Tagle and Claeys report that Popigai’s impact-melted rock has elements of chondrite meteorites, which are fragments of main-belt asteroids. (Chesapeake Bay crater’s origin is less certain because no melt rock has been seen there.)

Scientists think a rain of asteroid debris struck Earth 480 million years



POPIGAI CRATER may have four sibling craters from impacts around the same time. EARTH IMPACT DATABASE/ R. HAYES

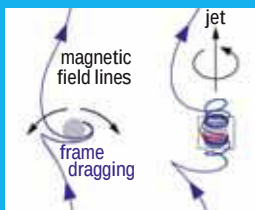
ago, and studies show more asteroid showers may have occurred, driven by perturbations from Jupiter’s gravity.

Three other craters on Earth have dates similar to Popigai and Chesapeake Bay. Asks Claeys, “Are the dates coincidence, or are smaller bits of asteroids falling during the same shower?” —R. B.

BLACK HOLES

Twist and shout

Big black holes in the centers of galaxies often shoot jets from their poles at nearly the speed of light. New theoretical work suggests the jets are driven by relativistic effects that occur



SPINNING BLACK HOLES drag space-time with them, winding up magnetic fields and powering jets. *SCIENCE*

close to the edge of a spinning black hole.

Vladimir Semenov (St. Petersburg State University, Russia) led a team that calculated that an effect in relativity called “frame dragging” could wind up magnetic fields around a black hole. They could then focus strong, narrowly directed jets of high-speed material shooting from each pole. —R. B.

HIGH-ENERGY ASTROPHYSICS

Black hole filling

An international team of scientists using two orbiting observatories has found more evidence that massive black holes are surrounded by donut-



A **DARK TORUS** deep in a galaxy’s core encircles a supermassive black hole that is shooting jets of energy. ESA ARTWORK

shaped clouds of gas and dust. With Integral and XMM-Newton, scientists looked edge-on into such a gas cloud, called a torus, surrounding a black hole in the spiral galaxy NGC 4388, about 65 million light-years away.

The team, led by Volker Beckmann (NASA Goddard Space Flight Center), saw how different processes around the black hole produce light at different wavelengths, but it is still unclear how the torus formed. The results of the study will be published in an upcoming issue of *The Astrophysical Journal*.

“This torus is not as dense as a Krispy Kreme donut,” says Beckmann, “but it is far hotter — up to a thousand degrees — and loaded with many more calories.” —PAMELA ZERBINOS

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PLANETARY SCIENCE

Moon rock odyssey

A meteorite found in Oman in 2002 can be traced back to the Imbrium basin and the crater Lalande on the lunar nearside, say scientists who studied the meteorite's isotope chemistry.

The fist-size meteorite named Sayh al Uhaymir 169 underwent three impacts while on the Moon before a fourth ejected it and sent it earthward.



SAYH AL UHAYMIR 169 (seen as found) is one of about 30 lunar meteorites discovered so far on Earth. *SCIENCE*

The researchers, led by Edwin Gnos (Bern University, Switzerland), found the meteorite consists of impact-melt breccia, a common lunar rock type built from fragments of other rocks welded together by shock. The meteorite contains more thorium than any lunar rock known. This points toward an origin in a thorium-rich area adjoining Mare Imbrium.

The study shows the meteorite's rocky material formed in a gigantic impact that occurred 3.909 billion years ago.

"We consider this first impact as the one that made the Imbrium basin," says Gnos. The second and third impacts occurred about 2.8 billion and 200 million years ago, respectively.

"The second impact made the crater Lalande," says Gnos, writing in *Science* (July 24, 2004). "And the third impact was from a crater close by." A fourth impact (so-far unidentified) came less than 340,000 years ago and threw the meteorite into space. About 9,700 years ago, it landed in the Omani desert. —R.B.

Can the X Prize help space research?

Those who saw the successful first space flight of an X Prize contender June 22 were struck by an unusual feature of the smoke trail. Unlike launchings toward orbit, which arc to the east to build horizontal speed, this white line across the desert sky went practically straight up, directly toward space.

It posed an obvious question. Besides carrying a pilot and perhaps paying tourists across the official boundary of space (100 km, or 62 miles), could such vehicles also carry research instruments, and at a price competitive with throwaway rockets?

Astronomy and other sciences have benefited from up-and-down rocket hops for more than half a century and still do. What contribution can this new generation of piloted, reusable rockets make?

NASA's project scientist for sounding rockets, Robert Pfaff of Goddard Space Flight Center, tells *Astronomy* the idea has a few problems.

"I don't see any advantages to human-tended suborbital flights for science missions, at least in space science," he says. Other scientists explain that their instruments need to go a lot higher, and dwell in zero-G a lot longer, than SpaceShipOne and its brethren can do.



CAN PRIVATE SPACE VEHICLES (such as SpaceShipOne) deliver sounding-rocket services for science research projects? NASA remains skeptical, but industry insiders think yes. *SCALED COMPOSITES*

"There might be some unique material-science experiment where a human presence is helpful," suggests Pfaff, "but most micro-gravity experiments flown in NASA's sounding rocket program prefer not to have humans on board to minimize vibrations."

He also points out that "NASA typically flies surplus military sounding rockets to altitudes of 60 to 80 miles — for which there is no cost to NASA for the motor hardware."

However, any mission still requires funding for range operations and payload costs, including all support personnel. In other words, even if the vehicles were provided free, X Prize suborbital rockets would have no cost advantage.

But several rocket builders have their own ideas about revolutionizing the sounding rocket world. Aleta Jackson, a spokesman for XCOR, which built the engine for SpaceShipOne and is designing its own non-

X-Prize vehicle called Xerus, says the company expects its vehicle could fly at a price perhaps 40 times lower than the million-dollar-plus sounding rockets.

"Add to this the greater likelihood of getting the payload back undamaged, the greater selection of onboard services — such as regulated electrical power — plus the potential to reflly an experiment within 24 hours, and you have a marketable vehicle," she says.

Furthermore, she continues, such a new tool is expected to attract new users. "The customers who have shown the most interest are generally not users of current sounding rocket flights. Therefore, we think this is more a case of bringing in a new group of customers than attracting them from existing missions."

How many of these new applications will be used in astronomy remains to be seen.

— JAMES OBERG



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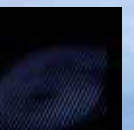
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GALACTIC ASTRONOMY

Big galaxy's violent past



NGC 5128 LIES 12.5 million light-years away in Centaurus and is the nearest giant elliptical galaxy. It has swallowed numerous small galaxies already, plus at least one large one. ESO

The 14 largest globular clusters in NGC 5128, a giant elliptical galaxy in Centaurus, may be the remains of destroyed dwarf galaxies, according to astronomers.

"These globular clusters are much more massive than most clusters in the Milky Way or the Andromeda Galaxy," says Paul Martini (Center for Astrophysics), who led the study carried out with Luis Ho (Carnegie Institution of Washington). They examined the clusters' motions and masses and published their results in *The Astrophysical Journal* (July 20, 2004).

Says Martini, "These 14 globulars are 10 times more massive than the smaller globulars in our neighborhood, and whatever process makes them can produce some really huge objects — they begin to overlap with the smallest galaxies."

Other astronomers have raised the idea of the largest globular clusters being remnants of dwarf galaxies. (One possible example in the Milky Way is the globular cluster Omega Centauri.) "However," says Martini, "globulars are much more centrally concentrated than the lowest-mass galaxies."

The difference pointed the astronomers toward a possible source for NGC 5128's massive globulars: a type of low-mass galaxy called a nucleated dwarf elliptical. If such a galaxy passed near enough to NGC 5128, it would be stripped of its outer stars, leaving only a globular-cluster-like nucleus.

NGC 5128, Martini notes, has grown to about twice the mass of the Milky Way. —R. B.

PLANETARY SCIENCE

New moons

Saturn and Neptune both have newly discovered moons orbiting in paths hinting at past upheavals, according to planetary scientists. The discoveries bring Saturn's moon count to 33 and Neptune's to 17.

Sebastien Charnoz (University of Paris) spotted a pair of 2-mile-wide moonlets in Cassini images. They orbit between Mimas and Enceladus with orbital periods of about one day.

At Neptune, Matthew Holman (Center for Astrophysics) and colleagues found five new moons, 20 to 30 miles across, outside the orbit of Nereid. Two moons orbit in the normal forward direction, three go backward. Their orbital periods range between 5 and 25 years.

Holman and team suggest the neptunian bodies are remnants of a former moon system scattered by Triton and Nereid, Neptune's largest moons. At Saturn, the orbits of the two new moons would be unstable over long time scales due to tugs from other moons. Thus the pair are likely relative newcomers in their present orbits. —R. B.

HIGH-ENERGY ASTROPHYSICS

Low-power gamma-ray bursts?

Last December, astronomers using the European Space Agency's Integral satellite detected a new gamma-ray burst (GRB) that emitted less energy than earlier ones.

On December 3, 2003, Integral saw a GRB that astronomers studied for months. Writing in *Nature* (August 5, 2004), team leader Sergey Sazonov (Space Research Institute, Moscow) reports that the burst, designated GRB 031203, was the second-closest GRB known, with a distance of 1.6 billion light-years.

The burst faded in the same way as more distant GRBs do, but emitted 1,000 times less energy overall.

Noting that an older and closer GRB, 980425, also seemed dim, the team cautions astronomers not to assume all GRBs have roughly the same power. —R. B.



GAMMA-RAY BURSTS are not all equally powerful. CXC ARTWORK

PLANETARY SCIENCE

Cassini discoveries at Saturn

Cassini has found that Saturn's radiation belts extend much closer to the planet than previously thought, say mission scientists.



TITAN'S ATMOSPHERE has two haze layers, the upper one being about 75 miles (120 km) thick. NASA/JPL/SSI

Radiation belts trap energetic electrons and ions in a planet's magnetic field. The new belt extends from the inner edge of the D ring down to just above Saturn's cloud tops.

Cassini also picked up bursts of radio waves from lightning in Saturn's stormy atmosphere. "We're detecting the same crackle and pop one hears listening to AM radio during a thunderstorm," says Bill Kurth (University of Iowa). The storms appear shorter-lived than the equatorial storms detected in the 1980s by Voyager and they seem to occur at higher latitudes. —FRANCIS REDDY

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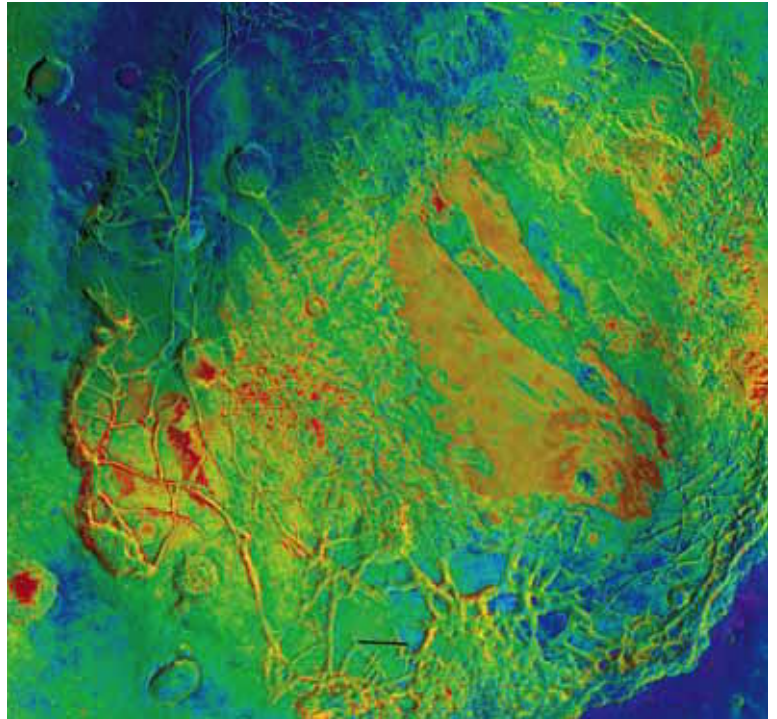
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Tharsis fractures



THE MARTIAN CRUST CRACKED as lava inflated the gigantic Tharsis volcanic bulge. The stress created these valleys in Sirenum Fossae that show automobile-size boulders rolling down the slopes. The image is about 1.9 miles (3 km) wide and lies near 28.9° south and 147.9° west. NASA/JPL/MSSS/IMAGE R10-03514

Cool dust and warm rock in Aram Chaos



COLORS MAP the nighttime temperatures in Aram Chaos, as seen by Mars Odyssey. Blue areas are cold (and likely dusty), red are warm (and rocky). It's not clear why some mesa tops appear free of dust. The image spans 200 miles (320 km). NASA/JPL/ASU

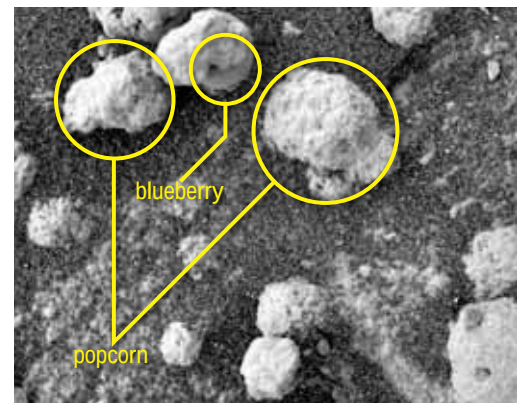
PLANETARY SCIENCE

"Blueberries," "popcorn" on Mars

Mars rover Spirit has found rocks in the Columbia Hills that are rich in sulfur, bromine, and chlorine, suggesting water has altered them.

In Endurance, Opportunity discovered "popcorn," a new type of spherule, light in color and with a rough texture. — R. B.

ON WEST SPUR, Spirit visits an outcrop (top) and spies Gusev's distant rim. Below, "blueberries" may be weathering out of "popcorn." NASA/JPL/CORNELL



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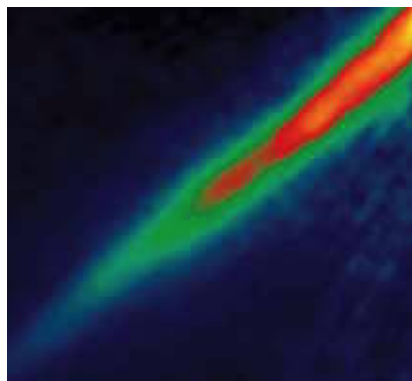
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STELLAR ASTRONOMY

The young planets of AU Microscopium

The dusty disk surrounding the star AU Microscopium contains clumps, bumps, asymmetries, and a warp. According to astronomer Michael Liu (University of Hawaii), who studied the star and its disk using the Keck II telescope, these features indicate planet formation is going on now within the



WARP AND WIGGLES in the dust disk around AU Mic point to planet formation going on at present. A planetless disk would be smooth and homogenous. IFA/KECK/M. LIU

disk. His report appeared in *Science Express* (August 12, 2004).

AU Mic lies just 33 light-years away. Cool and red, it shines with about a tenth the Sun's luminosity and has about half its mass. Theory says AU Mic formed about 12 million years ago, making it a reasonable age to be still forming planets.

"We cannot yet directly image planets around AU Mic," says Liu. "But they can't completely hide from us either. They reveal themselves through their gravitational influence, making patterns in the star's sea of dust grains."

An earlier study of AU Mic that focused on greater distances from the star found debris collisions in the disk were continually replenishing the disk's supply of dust — see *News, Astronomy*, June 2004. —R. B.

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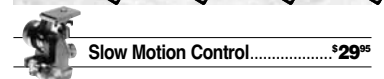
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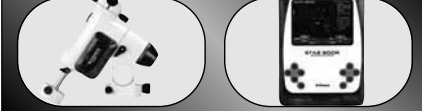
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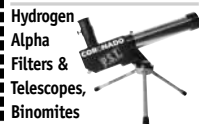
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The amazing lives of two stars

Pull back the curtain to see that stars — both big and small — are as dynamic and diverse as people. /// TEXT BY MARCIA BARTUSIAK /// ILLUSTRATIONS BY ROEN KELLY

The Sun is going to die.

Not soon, but eventually. While none of us is going to see it, astronomers continue to investigate our star's fate. In the same way they can predict the Sun's demise, scientists also study and model such fascinating events as the Sun's early formation and the dynamic molecular activity powering the hyper-productive, super-brilliant orb of energy. From its early formation from an interstellar cloud, to its twilight as a white dwarf, the Sun will experience numerous phases — the most stable of which, we're enjoying now. But what goes on inside that big, bright ball during its unstable phases? And how does our Sun's evolution compare to a star 15 times its size? Let's find out.

See "Red Sun dying" on page 40 to learn about the transition of the habitable zone in relation to the Sun's evolution.

[SOLAR-MASS STAR]



PHASE I: It begins with a nudge inside a small nebula. The push is forced by a shock wave passing through the galactic neighborhood. As a result, a roughly spherical clump of gas and dust, about a light-year in diameter, begins to collapse.

Like pizza dough whirling outward in the hands of a chef, the cloud spins faster as it condenses and flattens out. Under gravity's pull, the densest pocket of material collects in the center of the swirling disk of matter. A star, about the same mass and size of our Sun, has formed.

At the surface of this glowing sphere, the gases are spread thinly, their density just 1/10,000 that of air. Halfway toward the center, about a quarter-million miles in, the density of matter is comparable to water. But deep in the star's heart, where temperatures can exceed 10,000,000° Celsius, the density is 12 times that of lead. In this way, gravity has fashioned a wondrous power plant.

Racing within the stellar core, protons gain enough energy to overcome their electromagnetic repulsion and collide with one another, allowing them to stick together with a strong nuclear bond. Through an elegant series of chain reactions, four protons (in effect, four hydrogen atoms stripped of their electrons) are welded to create the heavier element helium, whose nucleus contains two protons and two neutrons. With each second, some 600 million tons of hydrogen are converted into helium. But along the way, a tiny fraction of that matter — less than 1 percent — is transformed into energy, according to Albert Einstein's famous equation $E=mc^2$. It is this radiation that makes its way through the star eventually to escape, bathing its surroundings in heat and light.

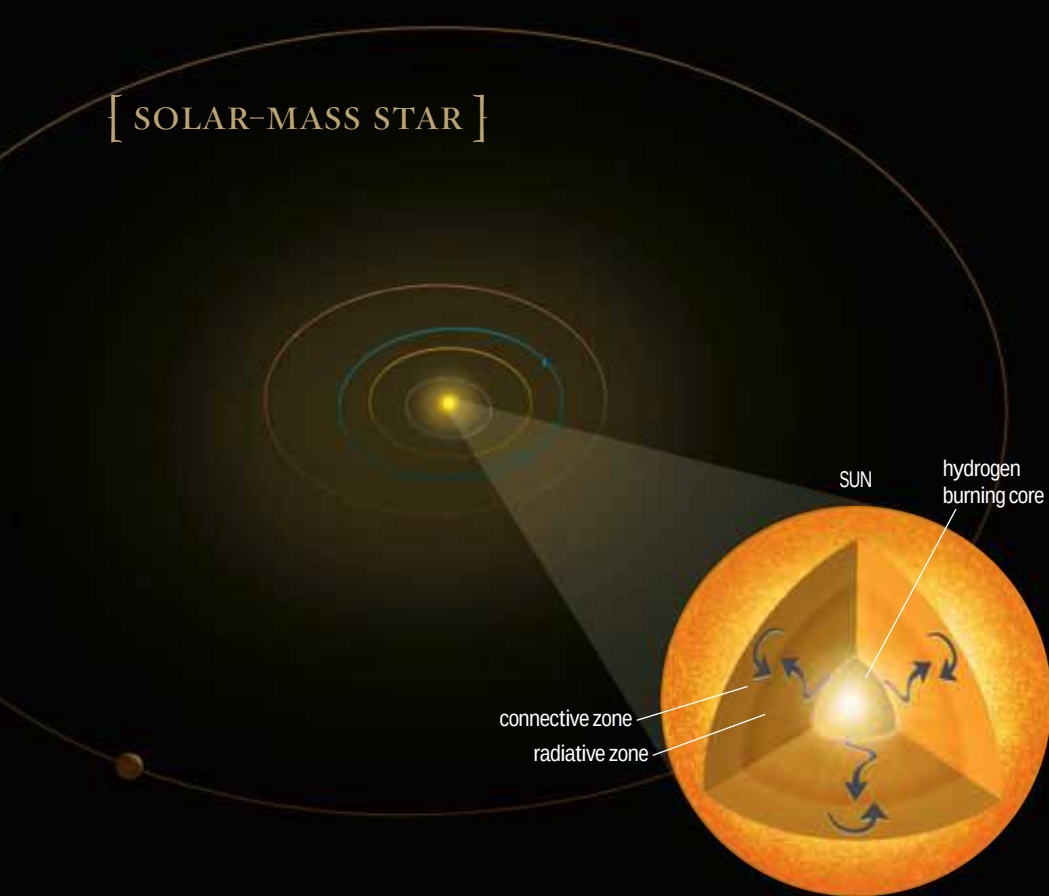
[15-SOLAR-MASS STAR]



PHASE I: A vast compression wave moves through a galaxy. Spiral shaped, the wave slowly ripples through the galactic disk, and a cosmic traffic jam ensues. As gas encounters this invincible wall of compression, it gets squeezed, forming huge clouds, dark and formidable. Some contain as much matter as 2 million suns. Temperatures

inside these clouds are cold enough for hydrogen molecules to form. After several million years, big, new stars turn on within these molecular clouds, illuminating the galaxy's spiraling form. These luminous stars — supergiants in size — live fast, burn bright, and die young. They perish even before they can move out of the traffic tie-up.

[SOLAR-MASS STAR]

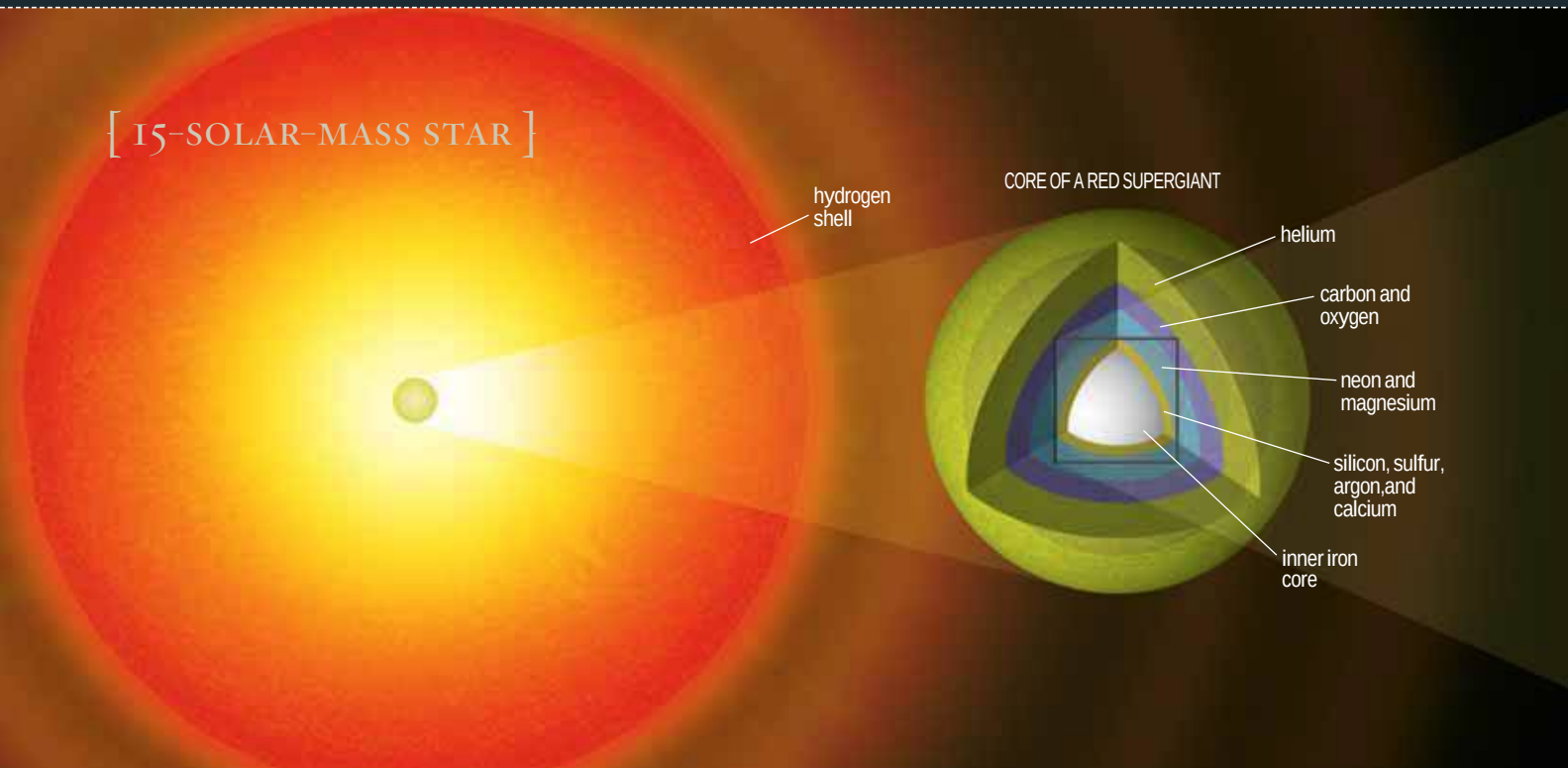


PHASE II: For eons, this process continues as the small star performs the universe's most amazing balancing act. While gravity pulls the stellar material inward, trying to squeeze it tighter and tighter, the pressure of the hot gases and particles bouncing around inside the star — energized by its ongoing nuclear reactions — acts as a counterbalance. Thus, the star's material neither disperses nor shrinks into oblivion. The star shines a brilliant yellowish-white.

But a star's fuel, while vast, is hardly inexhaustible. By 10 billion years after its birth, most of the hydrogen within this tiny star's core is converted to helium. The central furnace flames out, leaving the core inactive. Nuclear burning continues, but only in a shell of hydrogen surrounding the dormant helium core.

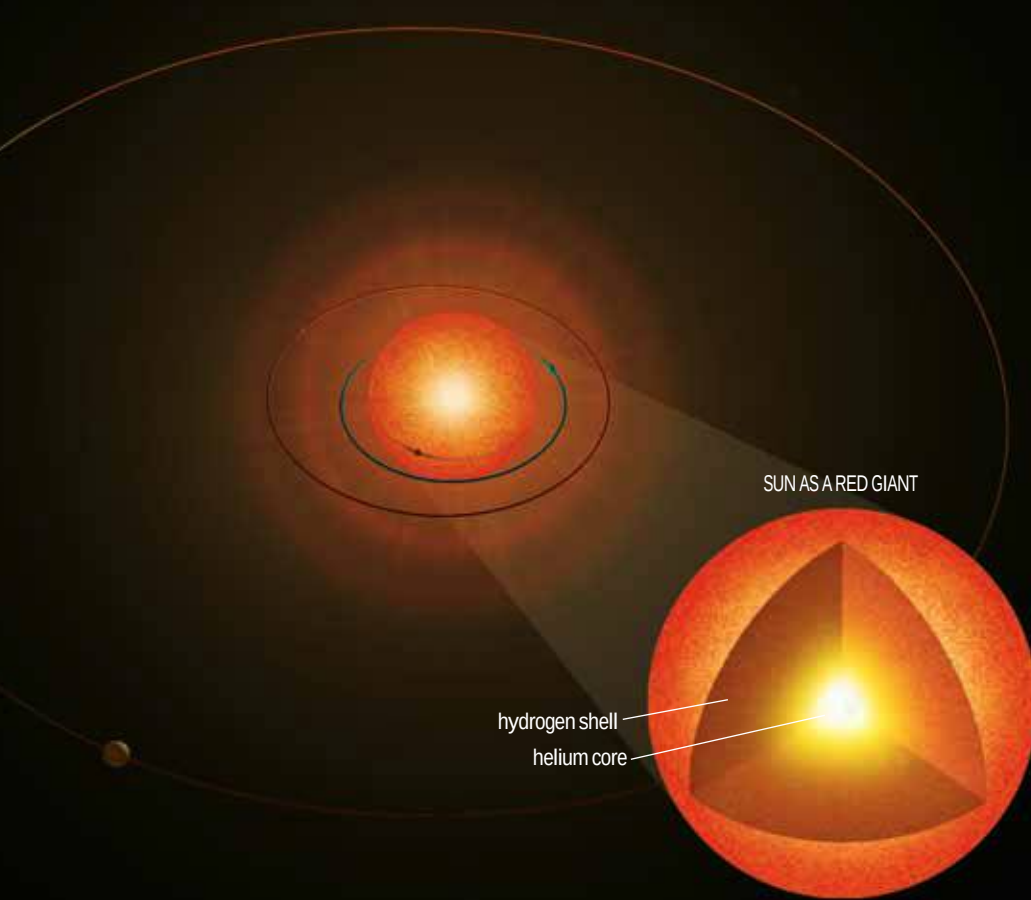
Marcia Bartusiak, a member of Astronomy's editorial advisory board, is a visiting professor with the graduate program in Science Writing at the Massachusetts Institute of Technology.

[15-SOLAR-MASS STAR]



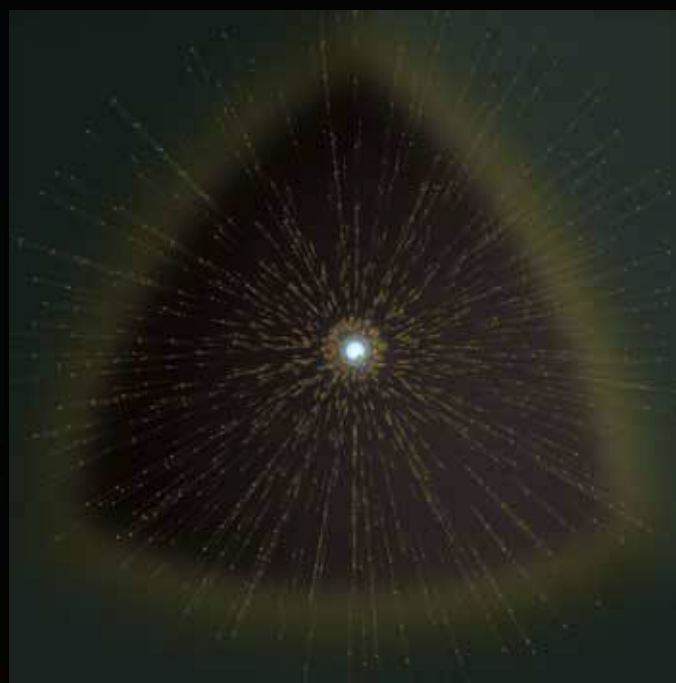
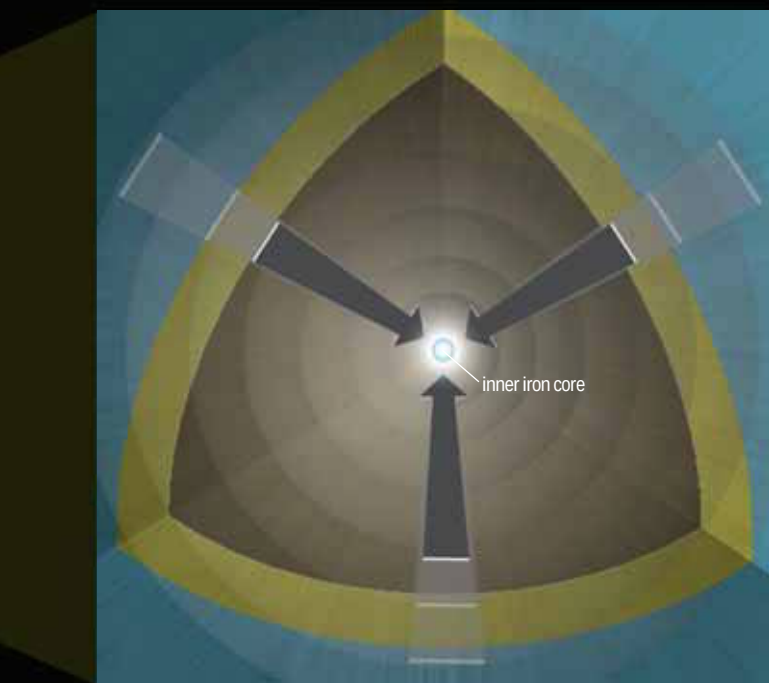
PHASE II: Like our Sun, a 15-solar-mass star first fuses hydrogen into helium for fuel, but it goes through its supply of hydrogen at an astounding clip, shining with the white-hot intensity of 50,000 suns. While our Sun takes some 10 billion years before its central nuclear furnace runs out of hydrogen and transforms into a red giant, this massive star accomplishes that task a thousand times faster. It expands to monstrous proportions, well beyond the size of a red giant.

PHASE III: The red supergiant develops a series of layers, like an onion skin, deep in its center. A hydrogen shell at first surrounds the dormant helium core and continues to fuse. As helium is added to the core, it ignites and begins to fuse into carbon and oxygen. Consequently, the carbon core is surrounded by a helium-burning shell, with a hydrogen-burning shell farther out. Squeezed inward and heated to a billion degrees, the carbon and oxygen nuclei fuse into



PHASE III: The star experiences one of the most dramatic mutations in the cosmos. It is the astronomical equivalent of a caterpillar's metamorphosis into a butterfly. Because the nuclear fire in the center of the star has been extinguished, the quiescent helium core, which is about the size of a giant planet, starts to contract. But in shrinking, the helium core and its shell of hydrogen generate energy that conversely pushes the outer envelope of the star outward. The star, formerly 1 million miles wide, eventually spans nearly 100 million miles, engulfing any planets within the stellar advance. The star's hue turns from yellow to a cooler shade, as temperatures decrease in the greatly expanded surface layers. The tiny star has become a red giant.

During this red-giant phase, new fusion reactions come into play. With the hydrogen-burning shell heaping helium on the dormant core, the center gets compressed — and heated. Once the core temperature reaches 100 million degrees Celsius, the helium ignites in a flash and starts to fuse into carbon and oxygen.



neon and magnesium. These, in turn, serve as the raw materials in the construction of even heavier elements, such as silicon, sulfur, argon, and calcium. Each chemical group burns in successive concentric shells. This fusion proceeds up the periodic table until iron is formed. Upon reaching iron, the star is at the end of the line. Instead of generating power, two iron nuclei require energy to fuse. It's a critical moment in this star's life. It faces its Waterloo.

PHASE IV: The iron begins to disintegrate because of the 10-billion-degree temperature in the star's core. Such destruction robs the stellar core of the energy that kept it intact. Without fusion-generated heat, the iron core can no longer withstand the force of its own gravity. In less than a second, the star's hidden core, which encompasses a volume about the size of Mars, collapses to the size of a metropolis. In the blink of an eye, a neutron star forms.

[SOLAR-MASS STAR]

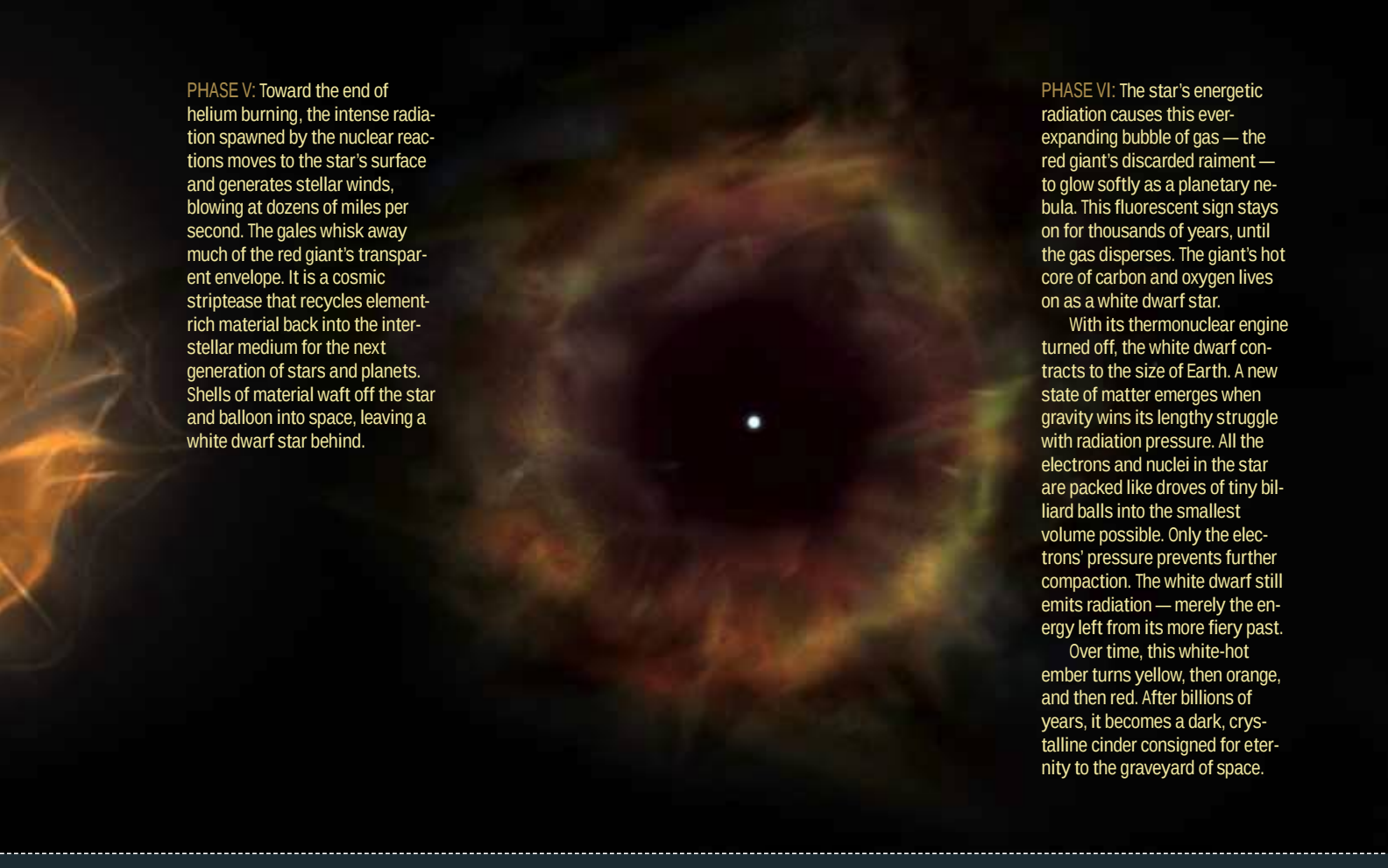
PHASE IV: The star shrinks back as it adjusts to its new fuel mixture. But during the next 100 million years, as helium begins to burn steadily, the star again expands. Once the rubylike orb reaches its full extension, it becomes one of the brightest stars in the galaxy for tens of thousands of years. Its brilliance nearly equals Aldebaran (the ruddy gleam in the eye of Taurus the Bull) and Arcturus (Boötes's brightest star, whose name signifies "guardian of the bear" for its nearness to Ursa Major and Minor). It may even pulsate at some point as a variable star.

[15-SOLAR-MASS STAR]

PHASE V: A white dwarf star resists further compaction due to electron pressures, but here, the gravitational force of the star's extra mass overwhelms that resistance. Now neutron pressures,

as well as nuclear forces, keep the star from gravitationally shrinking more. In essence, the neutron star is one huge atomic nucleus that happens to contain about a billion trillion trillion trillion

particles. Its creation releases a firestorm of neutrinos that speeds out of the star in all directions at near the speed of light, a prelude to a more visible event to come.

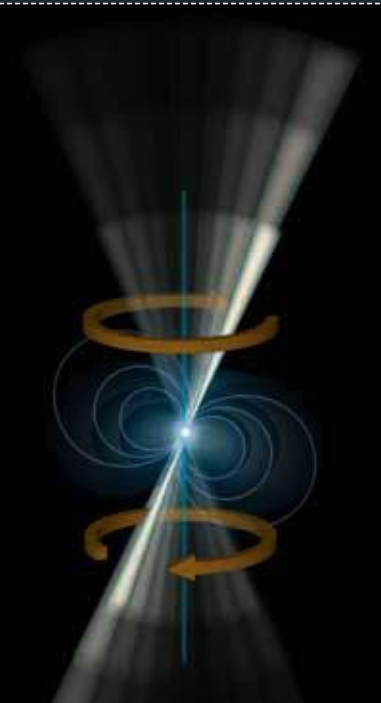


PHASE V: Toward the end of helium burning, the intense radiation spawned by the nuclear reactions moves to the star's surface and generates stellar winds, blowing at dozens of miles per second. The gales whisk away much of the red giant's transparent envelope. It is a cosmic striptease that recycles element-rich material back into the interstellar medium for the next generation of stars and planets. Shells of material waft off the star and balloon into space, leaving a white dwarf star behind.

PHASE VI: The star's energetic radiation causes this ever-expanding bubble of gas — the red giant's discarded raiment — to glow softly as a planetary nebula. This fluorescent sign stays on for thousands of years, until the gas disperses. The giant's hot core of carbon and oxygen lives on as a white dwarf star.

With its thermonuclear engine turned off, the white dwarf contracts to the size of Earth. A new state of matter emerges when gravity wins its lengthy struggle with radiation pressure. All the electrons and nuclei in the star are packed like droves of tiny billiard balls into the smallest volume possible. Only the electrons' pressure prevents further compaction. The white dwarf still emits radiation — merely the energy left from its more fiery past.

Over time, this white-hot ember turns yellow, then orange, and then red. After billions of years, it becomes a dark, crystalline cinder consigned for eternity to the graveyard of space.



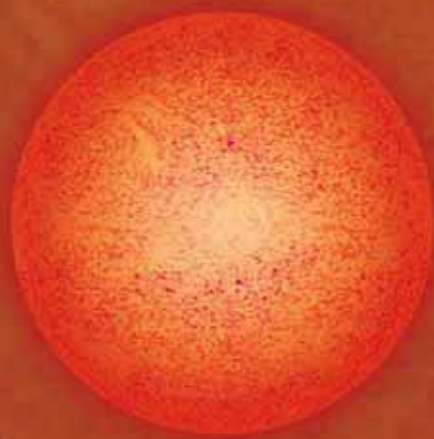
PHASE VI: A lone beacon remains. As the star's core collapsed to form the neutron star, it had to spin faster and faster, like a figure skater bringing her arms toward her body during a spin. It's simply conservation of angular momentum. In this situation, the star's magnetic field is compressed and intensified. A neutron star's magnetic field is more than a trillion times stronger than Earth's. Such a highly magnetized body becomes a gigantic electrical gen-

erator producing trillions of volts that enable charged particles to race away from the star's surface. Magnetic field lines channel the particles into two narrow beams that shoot out in opposite directions and emit a stream of electromagnetic energy, in frequencies from radio to X ray. These beams sweep around space, like a lighthouse beam skims a coastline. Radio telescopes, for example, observe each rotation as a pulse of energy, a periodic blip.

This "pulsar" marks the spot where the once massive star, too heavy to die quietly, tore itself apart as a supernova. The pulsar then spins a thousand times a second. After millions of years, it slows down and then is heard from no more. ■



To view animations of star formation, visit www.astronomy.com/toc



{ LIFE IN THE UNIVERSE }

Red Sun dying.



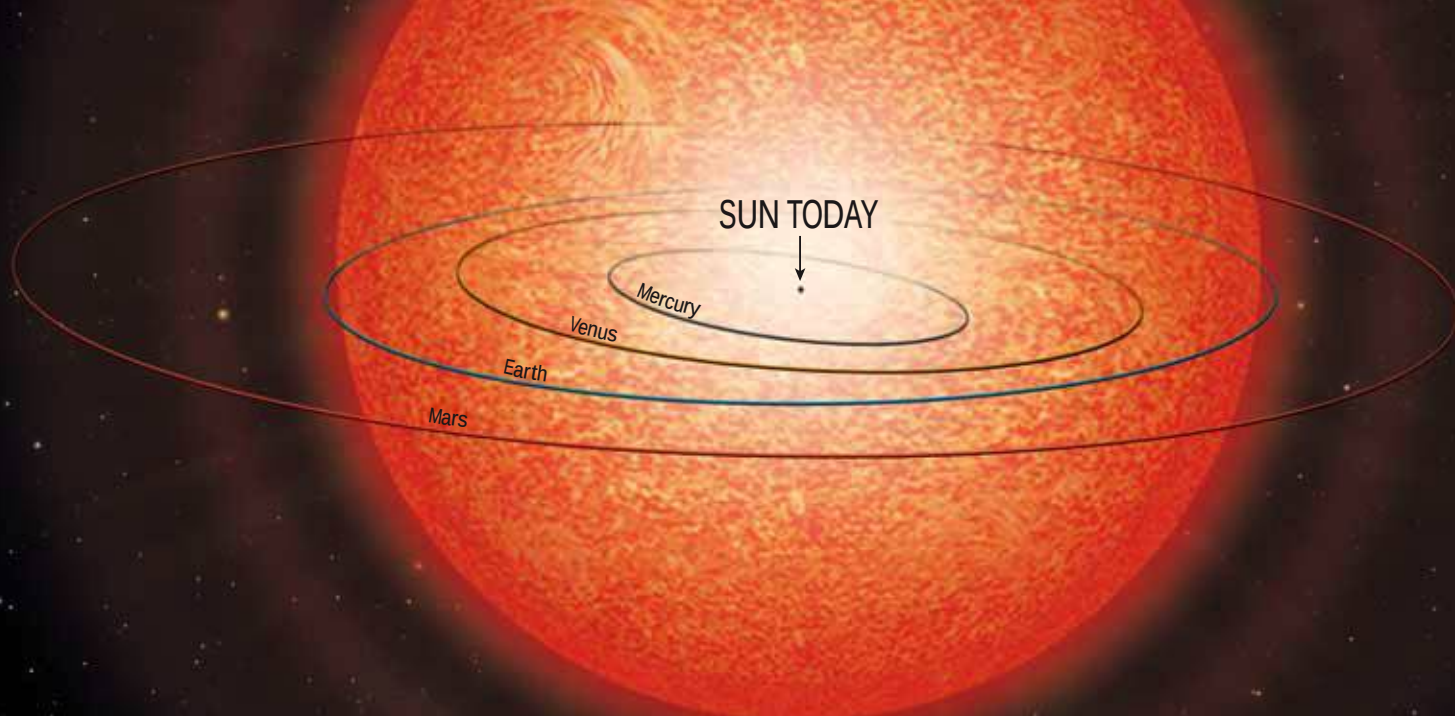
When the Sun becomes a red giant and scorches Earth, our solar system's habitable zone will move out to the region around Pluto. /// BY S. ALAN STERN

The discovery that planets around other stars

are common will forever stand as one of the great achievements of astronomy in the 1990s. As a working astronomer, this discovery came as little surprise. Given the run-of-the-mill nature of the Sun, I'd expected that the processes that led to the formation of planets in our solar system would naturally operate in other locales. What did surprise (and please) me, however, was learning that other solar systems would exhibit many exotic architectures.

I suppose this shouldn't have been any more a surprise to me than the variety of Earth's human cultures would be to a first-time globetrotter. Nonetheless, when searches turned up planets around pulsars and super-Jupiters orbiting their stars at Mercury-like distances, I felt enlightened. The variety of worlds these discoveries

THE RED GIANT SUN will consume the inner planets as it expands. Earth might escape incineration, but the temperature increase will boil the oceans and scorch the land, rendering the planet uninhabitable. ASTRONOMY: ROEN KELLY



SUN IN THE FUTURE

THE LATTER-DAY SUN will be at least 100 times larger and 2,300 times brighter than the Sun is today. As the Sun expands, its gravity will loosen, and planetary orbits will be pushed out. This may save Earth from being consumed wholesale, but prospects for continued life on the planet are dim — the red giant Sun will be hot enough and close enough to melt Earth's surface. ASTRONOMY: ROEN KELLY

suggested was as intoxicating as a first journey to a foreign land.

As I read and thought about the variety of planetary systems being discovered, I wondered how they might evolve. In our own solar system, we know the Sun is about halfway through its 12-billion-year “main sequence” phase. This phase will end when the Sun exhausts its supply of useable hydrogen fuel. When this happens, old Sol will puff up to about 100 times its present diameter, entering a stage of evolution called a red giant. For more about this process, see “The amazing lives of two stars,” on page 34.

As the Sun balloons, the inner solar system will roast; indeed, the inner planets may even be consumed by the expanding Sun. What does this mean for conditions in the outer solar system?

Miami Beach in the Kuiper Belt

To calculate what will happen to the outer solar system when the Sun goes red giant, we need to know the Sun's predicted mass, size, and luminosity over time. We also need a mathematical recipe for calculating

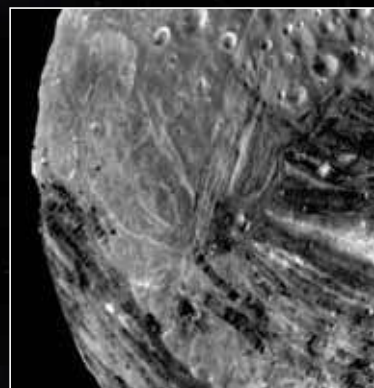
planetary temperatures using several variables, including the planet's distance from the Sun, the Sun's luminosity, and the planet's properties.

Information on the Sun's luminosity evolution is published in scientific literature. It's based on stellar evolution calculations that involve such criteria as nuclear fusion rates that control the rate of energy generation in the Sun's core, and the response of the Sun's outer layers to those internal processes. These calculations have been validated by observations of stars in different stages of their evolution.

We can use luminosity projections of the red giant Sun to calculate the approximate surface temperature of planets around the Sun (or another star) knowing only the distance of the planet from its star and the reflectivity of the planet. It's important to know this reflectivity, or albedo, because it tells us how much energy the planet can absorb and what its approximate temperature will be. The higher the

S. Alan Stern is a planetary scientist, pilot, and author. His most recent book, *Worlds Beyond*, was published in 2003 by Cambridge University Press.

Miranda — our new home?



Diameter: 293 miles (471 km)

Reflectivity: 27 percent

Surface temperature: -187°C / -305°F / 86 K

Surface composition: Water ice, silicates

Atmosphere: N/A

Zone: 19 AU

Miranda's spectacular features include huge fault canyons, terraced layers, and old and young surfaces; the Uranian moon is unlike anything else in the solar system. One theory speculates that the satellite may have been shattered and reformed as many as five times during its evolution, and the features suggest a surprising degree of tectonic activity for a satellite so small and cold. USGS

reflectivity, the lower the amount of energy the planet is able to absorb, and the cooler it will remain.

The actual temperature of a given planet will also depend on other factors, such as the degree of internal activity and the degree to which its atmosphere produces a greenhouse effect (i.e., whether miniscule like Mars's, mild like Earth's, or severe like Venus's). There are other complications, too. For example, during the red giant phase, a star's great luminosity and large size cause it to lose much of its mass. This causes planets to be bound less tightly to their stars and to move away to greater distances as the star loses mass.

For a common star like the Sun, the room temperature distance moves outward late in life from the 1 astronomical unit (AU) distance we know and love here on Earth to as far as 50 AU. Similar, but more extreme, behavior is exhibited in stars with higher masses. But the basic message remains unchanged: The cozy, warm kind of "habitable zone" around each star will move outward as the star gets older, moving from the inner to the outer solar system. The lesson for astrobiologists is clear: Which planetary abodes in a given system are habitable depends on what phase of evolution the system's star is in.

Water worlds waiting

A few billion years from now, when the terrestrial planets suffer a fate somewhere between roasting and evaporating, the ice worlds of our solar system will melt and become ocean oases for tens to several hundreds of millions of years. Our solar system will then harbor not one world with surface oceans, as it does now, but hundreds — all the icy moons of the gas giants, as well as the icy dwarf planets of the Kuiper Belt, will bear oceans. Pluto's temperature will resemble Miami Beach's current temperature, so I like to call these worlds "warm Plutos" in analogy to the plethora of "hot Jupiters" found orbiting Sun-like stars in recent years.

Will these worlds evolve life? We don't know. Arguing against "much interesting" happening on these worlds is the comparatively short amount of time (millions of years instead of billions) during which these distant oases can persist before the Sun's luminosity declines and their oceans refreeze forever.

Triton — tropical paradise?



Diameter: 1,680 miles (2,700 km)

Reflectivity: 70 percent

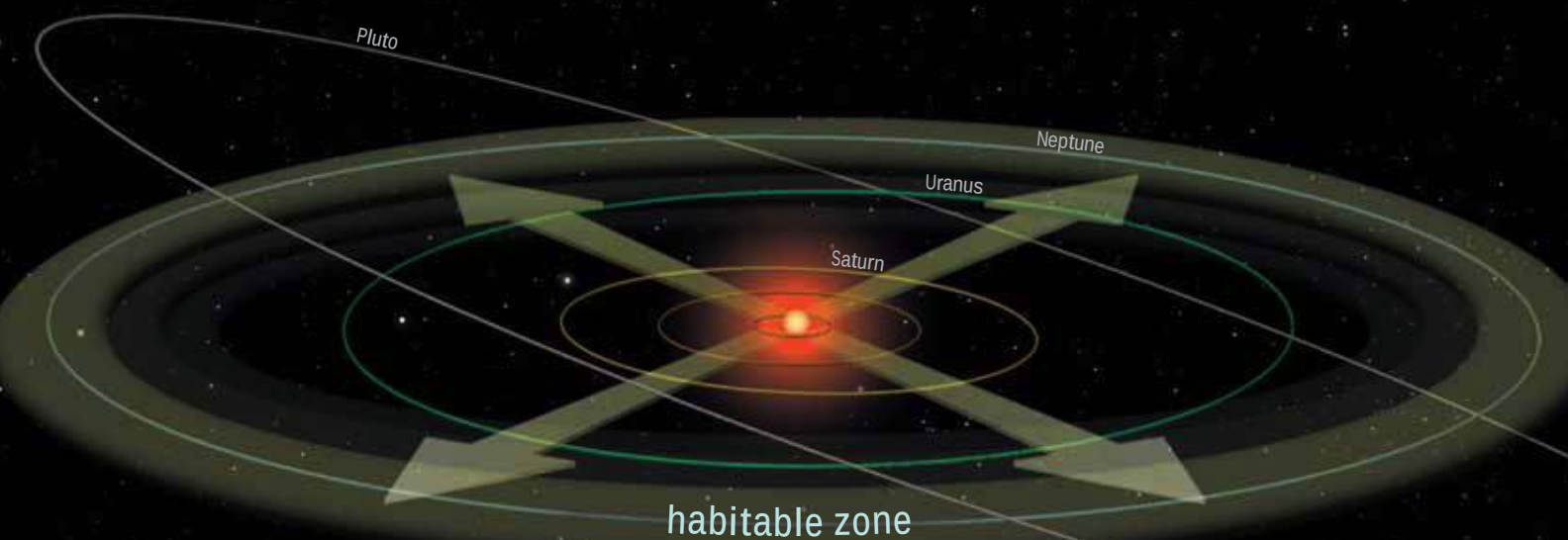
Surface temperature: -235°C / -391°F / 35 K

Surface composition: Nitrogen, water, carbon dioxide, carbon monoxide, methane

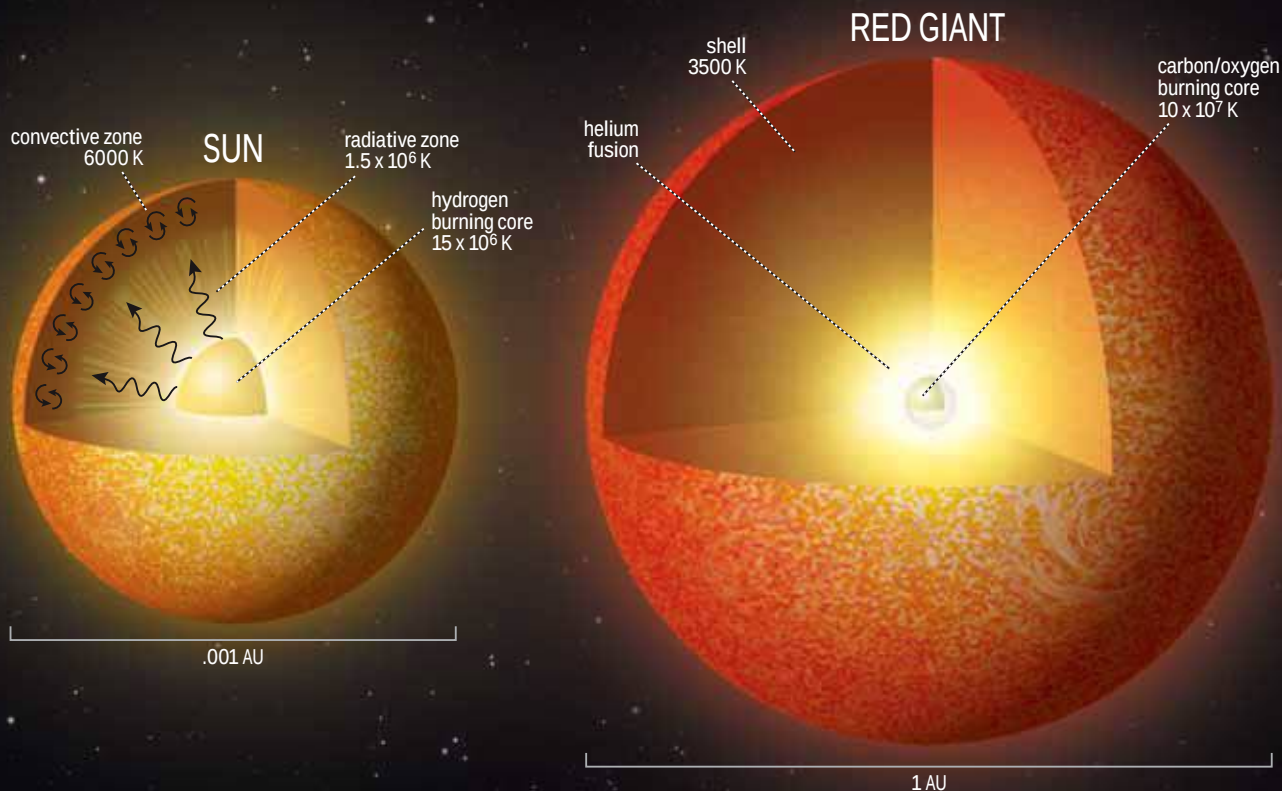
Atmosphere: Nitrogen, methane

Zone: 30 AU

Lakes of liquid nitrogen or methane once found on Neptune's largest moon, Triton, have long since frozen solid, although the satellite's thin atmosphere continues to teem with hydrocarbons. Even so, Triton's highly inclined axis makes the moon an unlikely candidate for comfort, as the seasons vary wildly from one year to the next. USGS



A STAR'S HABITABLE ZONE (HZ) is the region where liquid water can exist on a planetary surface. The Sun's current HZ extends from about 0.95 AU to 1.37 AU, with Earth in the middle at 1 AU. In a few billion years, when the Sun depletes its hydrogen supply and goes red giant, it will be 2,300 times brighter than it is today, pushing the HZ to the outer reaches of the solar system where Pluto and other Kuiper Belt objects orbit. ASTRONOMY: ROEN KELLY



IN 6 BILLION YEARS, the Sun will have made it through its 12-billion-year “main-sequence” phase, which is marked by the fusion of hydrogen in the Sun’s core. Once the Sun runs out of hydrogen, it will turn to heavier fuels such as helium to sustain its fusion fires. These elements require higher core temperatures to fuse, and Sol’s center will reach 100 million kelvins. ASTRONOMY: ROEN KELLY

Enceladus — white knight?



Diameter: 309 miles (498 km)
Reflectivity: 99 percent
Surface temperature: -203°C / -333°F / 70 K
Surface composition: Water ice, silicates, methane ice
Atmosphere: N/A
Zone: 9.5 AU

Saturn’s moon Enceladus would be a cold comfort, despite its surface of hydrocarbons. Its extremely high reflectivity — think of freshly fallen snow — means it absorbs almost no heat from the Sun; its current temperatures are comparable to those of Uranian satellites, despite being almost 10 times closer to Sol. USGS

But such systems won’t suffer the kind of life-threatening bombardment that Earth had to endure in the raucous, early, post-planet-forming era of the inner solar system. The swelled Sun won’t produce as much harmful UV radiation. And unlike, say, present-day Mars, the ice worlds of the outer solar system already are teeming with hydrocarbons and other organic compounds. Who is to say what stew those myriad future oceans may someday brew?

Looking for life

We do not yet know if our solar system is “normal.” Indeed, we do not even know if icy worlds at tens of astronomical units from their stars are common. But we do know there are some 10 billion red giants in the Milky Way, and if our small piece of the galactic neighborhood is normal, the kind of outer solar system our home star will sport someday exists now around some of these red giants.

The Kuiper Belt, in our outer solar system, has at least a million ice-rich worlds, with at least three times the surface area of the four innermost

planets. Over 99 percent of our solar system’s water and other organic material is found in these far-out habitable zones — and not in the familiar 1 AU zone. These far-out worlds therefore represent an important niche in the spectrum of habitable zones nature may fill with life. Sure, there are details to be worked out regarding the effects of stellar luminosity pulsations and stellar winds. And yes, there are other details to consider regarding the effects of red giant radiation on habitats and the evolution of planetary atmospheres and their greenhouses on warm Plutos.

Nevertheless, the basic message is clear: Just as the kinds of worlds discovered in the 1990s, including pulsar planets and hot Jupiters, were different from those in our home system, so too the worlds potentially sporting life in our galaxy may be different from the one supporting life in our solar system. What a wonderful universe of possibilities awaits us as we continue to explore. ■



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{ SPACE TELESCOPES }

The looming DEATH of Hubble



Refurbishing the Hubble Space Telescope by robot will fix an urgent problem. But it still will leave astronomers without an optical space telescope within a decade. /// BY ROBERT ZIMMERMAN

Without question, the Hubble Space Telescope (HST) is the grandest instrument humans have ever sent into space. For more than a decade, it has churned out image after image, many of them profoundly changing

our perception of the universe. Conceived in the 1960s, HST's gestation was long and difficult as scientists, bureaucrats, and politicians fought over its design. Built in the 1970s and 1980s, its career was at first stillborn, as astronomers discovered its mirror was defective. Fixed at the expense of one instrument and maintained throughout the 1990s by high-flying astronauts who loved it as much as the scientists who used it, HST has unfolded for us a view of the universe so profound that no human will be able to look at the stars in the same way again.

And then, even as HST was reshaping our perceptions, everyone decided to abandon it — the astronomers who depend on it for research, the politicians who revel in the reflected light of its glorious imagery, and the bureaucrats charged by the public to keep it running. Hubble was to be allowed to die and drop into the ocean. NASA would build a replacement telescope working in the infrared, and optical astronomy would return to using big ground-based telescopes alone.

The public, however, has not been so willing to bow to the decisions of the power-broker elite. Their taxes paid for Hubble; they feel it is important to have a space-based optical telescope. And they have forcefully told the decision-makers to rethink the idea of abandoning Hubble.

What will happen during the next 3 to 4 years, which is about how long engineers think HST has left, probably will be decided in the next year. The decision will be made in the halls of Congress, in the offices of NASA, and in other scientific institutions. And most important, the decision will be informed by the national outcry from millions of Americans who love astronomy and the space telescope that serves them.

On February 1, 2003, the space shuttle Columbia tragically broke up during reentry from orbit after 17 days of scientific research in space. The consequences of that failure have been far-reaching and still have not played out. As of today, a year and a half later, no shuttles have flown, and the next flight still lies at least 6 months away. The Columbia accident not only forced NASA to rethink its safety program, it caused President George W. Bush to rethink the purpose of the country's space program. On January 14, 2004, he announced a complete reshaping of NASA's objectives. The new focus is exploration, leading to a manned return to the Moon by 2020, followed by an eventual manned mission to Mars. The space shuttle would be used to complete the International Space Station by 2010, then retire. Work at the station itself would center on solving the problems of long-term space flight in preparation for future interplanetary



UPGRADING A SPACE TELESCOPE in orbit (above) isn't easy, as astronaut crews have found on the four manned servicing missions carried out so far. Their experiences led many of them to question how well a robot could do the job. NASA

FROM ITS LONELY PERCH in space (left), the Hubble Space Telescope has changed our view of the universe forever. It needs refurbishment to continue working. But how NASA handles the issue will have a major impact on all of optical astronomy for years to come. NASA



1 **GRAPPLING HUBBLE** with its robotic arm, the chase vehicle docks at HST's aft end. The chase vehicle has two modules. The gold-colored ejection module carries the new instruments and gyros plus a double robotic arm. The main arm is used for holding while the other, called Dextre, folds out of the main arm for detailed work. The blue de-orbit module carries avionics, new batteries, and the rocket engine for taking Hubble out of orbit. NASA/GSFC

missions. The manned program would build a wholly new spacecraft, tentatively dubbed the Crew Exploration Vehicle, for accomplishing these goals.

Under this new vision, the only shuttle flight that would *not* go to the International Space Station is the fifth and last planned servicing mission to Hubble. Tentatively scheduled to fly in 2006, the servicing flight would install two new scientific instruments, replacing the Wide-Field Planetary Camera 2 (WFPC2) with the Wide Field Camera 3 (WFC3) and adding the Cosmic Origins Spectrograph (COS).

More important, astronauts would do essential maintenance, including replacing the telescope's failing gyroscopes and giving it a new set of batteries. Without replacement, Hubble's old gyros

The final servicing mission to Hubble, however, would have no such safe haven because the telescope's orbit makes it impossible for a damaged shuttle to go from Hubble to the station. According to NASA, the agency would have, at most, 18 days after launch to inspect the orbiting shuttle and, if necessary, mount a rescue mission. Under these stringent safety rules, and with the agency's basic mission being refocused toward the human exploration of the Moon and Mars, O'Keefe decided the Hubble servicing mission was just not worth it.

Uproar

Neither O'Keefe nor anyone else, however, was quite prepared for the public's response. Soon NASA was bombarded by 400 e-mails

The Columbia disaster forced NASA to rethink its safety efforts – and led the White House to rethink the purpose of the country's space program.

and batteries are expected to fail during 2008. With them, Hubble should function for at least another 5 years.

Decision

Two days after Bush's announcement, however, NASA Administrator Sean O'Keefe shocked the scientific community and the public by announcing the last shuttle servicing mission to Hubble was canceled. He did this, he said, after considering the president's proposals as well as the agency's desire to meet all the recommendations of the Columbia Accident Investigation Board. As he noted in later testimony before Congress, "This was among the most painful decisions I've ever had to confront."

O'Keefe explained that the board's recommendations required that no shuttle fly unless there is a way to inspect and repair its wings and thermal protection system in orbit. Such capabilities exist at the International Space Station, where a shuttle and its crew would have a 60- to 90-day safe haven should the shuttle be damaged during launch.

Robert Zimmerman has been writing about Hubble discoveries for Astronomy for more than a decade. His most recent book, *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel*, was published by Joseph Henry Press.

a day in protest, and during the next few weeks, editorials and opinion pieces in dozens of newspapers across the United States came out against the decision. At the same time, several grassroots organizations started letter-writing campaigns and petitions protesting the decision. One web page gathered almost 40,000 signatures in less than 2 months. In Congress, a resolution was introduced demanding that an independent review be done before any final decision on Hubble's future be made. Soon thereafter, a committee was formed at the National Academy of Sciences to assess Hubble's future.

As *The Denver Post* noted in a strongly worded editorial March 22, 2004, "The public and Congress are letting NASA know they understand the real value of the Hubble Space Telescope — even if NASA doesn't."

Faced with the outcry, the space agency put out a call for ideas on how to fly an unmanned servicing mission to carry out the tasks using robotic and remotely operated technology. To its surprise, NASA quickly received more than two dozen proposals, including scads of data on a plethora of already-built and available robot arms. One arm was being developed only a few miles from Washington, D.C., at the University of Maryland in College Park. Another was being tested at the Johnson Space Center in Houston. A third, built by the Canadian Space Agency — the



2 THE "DEXTROUS" ARM CONNECTS Hubble's new batteries (in the blue module) to the solar panel arrays using external connections employed by astronauts on previous servicing missions. Although it has not yet flown, Dextre is already built and space-hardened because it was designed for use on the International Space Station, where it would be controlled by astronauts inside the station. NASA/GSFC

people who built the robot arms for the space shuttles as well as the International Space Station — was ready to fly. A two-armed robot grapppler named Dextre, it was built for use on the space station and was already space-hardened.

At the Goddard Space Flight Center in Greenbelt, Maryland, engineers whose job was to build and run the canceled shuttle servicing mission found themselves scrambling to figure out some way to save Hubble, working under the assumption that a manned mission was forbidden.

Tests at Goddard using one of the available robot arms suggested that such an arm could perform most of the necessary tasks for servicing Hubble. Engineers designed and built several dozen special tools, which they attached to the arm and used on a duplicate ground-based version of Hubble to open its panels, remove internal units, and insert some replacement components. The engineers also found the robot arm could disconnect and reconnect several different electrical plugs.

Piggyback

The United States has signed international treaties that require it to prevent any objects from returning to Earth in an unsafe and uncontrolled manner. Therefore, NASA had already budgeted \$300 million to fly a robotic de-orbiting mission. The robotic craft would dock with Hubble around 2010 and use its engine to bring down the telescope soon thereafter.

The flight plan called for the module to rendezvous with Hubble, use a robot arm to grab the telescope by the same handles used by the shuttle's arm, and then attach itself to Hubble's aft connections. When the time came to de-orbit Hubble, the module's rockets would fire so the telescope would re-enter the atmosphere and burn up safely over the ocean.

The Goddard engineers quickly worked out what they called a "straw-man concept" for a robot maintenance mission, piggy-backed onto the de-orbit module. A second, independent module would be attached to the de-orbit module, carrying both the



GALAXIES AND COSMOLOGY were the specialty of astronomer Edwin Hubble, the space telescope's namesake. Here, the Sombrero Galaxy (M104) in Virgo displays its central ring of dust backlit by uncountable billions of stars. By providing clear images of this and many other distant galaxies, the Hubble Space Telescope has redefined the visual universe, for astronomers and the general public alike. NASA/STScI



3 OUT WITH THE OLD, in with the new. Dextre removes the old Wide-Field Planetary Camera 2 and slides its replacement into the instrument bay. The new Wide Field Camera 3 carries the telescope's new gyros attached to the outside of the instrument. This solves the thorny problem of having a robot working inside Hubble's rear compartment, where astronauts found gyro replacement was difficult due to tight clearances. NASA/GSFC

WFC3 and COS, plus new batteries and gyros. Using its robot arm, this so-called chase vehicle would plug the batteries into the same outlet used when HST was docked with a shuttle, thereby linking them in a simple manner to Hubble's electrical system.

Replacing Hubble's gyros, however, seemed too risky for any robot. To provide the necessary stability, the gyros attach directly to Hubble's internal frame. They are located near the aft end of the telescope, accessible through two doors that open by retracting two seals and four latches. The gyros are held in place with two electrical connectors and three hex-socket bolts. Astronaut Greg Harbaugh remembered replacing the gyros when he flew to Hubble in 1997: "You had a guy in there like he was working on his car. Very difficult access — difficult visibility."

dard) — to build and launch a robot mission by December 2007 requires that "we get contracts in place by October 1st [this year], or very, very close to that. If you go much beyond that, whether you like robotic missions or not, you lose the [robotic] option."

"Hubble has a date with destiny," said Frank Cepollina, project manager for the previous manned shuttle missions at Goddard. "We cannot wait."

Doubts

Designing, building, and launching a robot mission before December 2007, however, is not going to be easy and, according to many people in both the astronomical and aerospace communities, it may be impossible.

That NASA intends to send an untested robot on a mission to dock with Hubble and fix it sends nervous chills down astronauts' spines.

Then the Goddard engineers had what you could call a "eureka!" moment. Rather than install the gyros separately, the engineers would attach them to WFC3 while it was still on the ground and the robot would install the whole assembly on Hubble. Unlike the gyros, installing WFC3 is far easier. There are no doors to open and close or electrical connections to plug in. Instead, the outside wall of the instrument forms the outside of Hubble, while the electrical connections plug in automatically when the unit slides into place. The robot would attach a handle to the old WFPC2, unlatch two bolts, then pull the obsolete unit out on its rails. When the robot arm slides the new WFC3 into place, its electric connections will plug in, automatically powering up the gyros as well.

With Goddard's detailed concept of a robotic mission in hand, O'Keefe stood before a thousand astronomers at a meeting of the American Astronomical Society June 1, 2004, and announced that "NASA is releasing a call for proposals today for a robotic Hubble servicing capability." Although the request's primary purpose was to start work on the de-orbiting mission, the agency also was looking for detailed proposals to combine it with a robotic servicing mission.

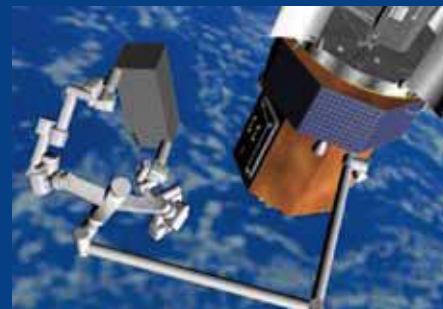
As noted that same day by Ed Weiler (then NASA's associate administrator for space science and currently director of God-

During the summer of 2004, the committee at the National Academy of Sciences held open and closed hearings for assessing how to extend Hubble's life. They heard from NASA and from industry experts, including O'Keefe and Admiral Harold Gehman, chairman of the Columbia Accident Investigation Board.

Gehman noted that, despite NASA's decision to cancel the Hubble servicing mission because of the difficulties of meeting the board's recommendations, the report actually left NASA much flexibility. "We clearly gave NASA the operational freedom to [send the shuttle] to Hubble," he said. He also noted that although it appeared slightly safer to go to the International Space Station than to go to Hubble, the differences were "not a big deal" to the accident investigation board.

Other industry experts noted how risky it will be for an untested robot to grapple Hubble. As Darryl Sargent, director of space systems at Draper Industries, put it, "We are fairly concerned about the use of dextrous robots [as well as] the ability to do it without extensive flight testing." He also described how the time delay in communications between a ground controller and the robot in orbit could pose significant difficulties.

Nor have the hearings at the National Academy been the only place where doubts have been expressed. As stated by Jerry Grey of Princeton University, "Most robotic systems of this type, by the



4 THE COSMIC ORIGINS SPECTROGRAPH, or COS, goes inside the instrument bay after the dextrous arm opens the access panels and removes COSTAR, the obsolete corrective optics package installed on the first servicing mission in 1993. The COS's capabilities largely replace the Space Telescope Imaging Spectrograph (STIS), which developed problems and was shut off in August 2004. In addition, COS has 10 times the sensitivity of STIS. NASA/GSFC

time you put them up into space, the chance of something going wrong is so great, it's a high risk. You're doing something that's never been done before."

To others, a manned shuttle servicing mission remains the only practical way to service Hubble. In a blunt expression of their concern, May 26, 26 astronauts signed a letter petitioning President Bush to "reinstate the Hubble Space Telescope servicing mission." The astronauts noted how "any robotic servicing will require . . . flying a first-time-ever, unmanned rendezvous and docking mission to the Hubble and would have a lower probability of success [than a shuttle mission]."

The United States has never attempted to build an automatic docking system, and only Russia has done repeated robotic dockings. Moreover, both nations developed their present docking systems through difficult tests that involved numerous failures, a number of near-collisions, and several crashes, one of which almost destroyed Mir, the former Russian space station. That

NASA intends to fly a quickly assembled robot mission and send it *untested* to dock with Hubble — which has no radar equipment of its own and was not designed for a robot docking — sends nervous chills down these astronauts' spines.

And then there is the concern that a failed robot mission would not only mean the end of Hubble science research, it could leave Hubble tumbling out of control, lacking any method for bringing it down safely and in a controlled fashion.

In contrast, the astronauts noted, "the space shuttle is a magnificent system." Manned shuttle missions already have serviced Hubble four times, and in the process, not only fixed the distortion in Hubble's main mirror, they replaced practically all of Hubble's scientific instruments, upgrading its capabilities far beyond what it had on launch in 1990. Extensive experience by astronauts and the available technology of the shuttle means that, to these astronauts, "a shuttle servicing mission would be more cost effective than the proposed robotic mission."



THE LOSS OF HUBBLE, whenever it occurs, will leave optical astronomy without a space telescope. Views such as this of star-forming region N11B in the Large Magellanic Cloud will become a thing of the past. A new optical space telescope with the power of Hubble will take most of a decade to design and build; none is yet on the drawing boards. NASA/STScI



5 REFURBISHING COMPLETED, the ejection module separates from Hubble, leaving the de-orbit module still attached. The telescope can then continue scientific operations for about another 5 years. When the reprieve expires, the de-orbit module fires its engine to bring Hubble down safely, probably dropping it into the Pacific Ocean. NASA/GSFC

After Hubble, what?

Lost in the how-do-we-save-HST discussion is the long-term question of Hubble's ultimate life span, and the continuing need for an optical space telescope after Hubble is gone.

Even if a robotic mission successfully services Hubble, as presently conceived such a mission would extend Hubble's life span only 5 years to around 2012, when Hubble would be de-orbited. Once a robot module docks to Hubble's aft end, its presence makes it difficult, if not impossible, for a later mission to service Hubble. This means a robotic servicing mission pretty much guarantees Hubble's loss by 2012 or soon thereafter.

A shuttle-based servicing mission, however, would at least leave open the option of sending either another shuttle or a more

ble could be designed, built, and launched any earlier than about 2020, given how long space telescopes take to be developed. (See "Beyond Hubble," *Astronomy*, October 2004.)

Decision, 2.0

On August 9, 2004, NASA Administrator O'Keefe strongly endorsed a robot mission during a visit to Goddard. However, no final decision has been made, and there is still time to reinstate a manned servicing mission. According to engineers, to fit a Hubble mission into the planned shuttle schedule, the mission must fly in spring 2007 and would need 19 to 24 months to prepare for flight. Thus the final decision whether to fly a robotic or manned servicing mission must be made no later than December 2005.

No optical space telescope is being built to replace Hubble. After it comes down, optical astronomy will be solely ground-based.

sophisticated robot mission to Hubble sometime around 2011. This could keep the space telescope flying well into the 2010s and perhaps beyond. As the astronauts' petition noted, "The early retirement of this observatory . . . blinds an incredible probing eye into the mysteries of the universe and the associated vital answers about its past and future."

And losing Hubble is no trivial matter for astronomers. At this moment, there is no optical and/or ultraviolet space telescope being built. In the 1990s, the astronomical community made the decision, perhaps tragic in retrospect, to depend on ground-based optical telescopes in the post-Hubble era, and having Hubble's replacement, the James Webb Space Telescope (planned for launch in 2011), work almost entirely at infrared wavelengths.

Just last year, however, astronomers finally recognized the need for an optical space telescope. In August 2003, a NASA-picked committee of scientists recommended that not only should the planned fifth shuttle servicing mission be flown, but NASA should seriously consider an additional sixth servicing mission to extend Hubble's life past 2011. And as if to keep all options open, this past July, NASA chose for further study a proposal that would fly the COS and WFC3 on an independent mission.

Once a robot mission de-orbits Hubble in 2012, however, there would be no optical capability in space. No replacement for Hub-

Moreover, the report of the National Academy committee is due in November 2004, and its recommendations, as yet unknown, will have a great impact on what happens. Both O'Keefe and Weiler told the committee they are open to any substantive advice the committee might offer and they would be eager to see an interim report if possible. As O'Keefe said during his testimony, "I am anxious to hear your learned opinion."

Although politicians, bureaucrats, and scientists might not have realized it before the public chimed in, everyone now recognizes that losing Hubble would be a scientific tragedy. Without Hubble to inspire the public and stimulate funding for less famous space telescopes, the likelihood is slim that American space astronomy will thrive after Hubble fails.

Hubble's loss also would be a tragedy for American culture. The Apollo Moon landings earned the United States a heroic place in history. The failure of the nation to successfully follow them up, however, has labeled the United States as a country that dropped the ball. It would be a terrible shame if we repeat this error, and become known as the nation that let the first and greatest optical space telescope fall into the ocean needlessly. ■



For more on NASA's capability to save HST by sending a robot, visit www.astronomy.com/toc



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NOVEMBER 04

Beautiful Saturn commands the late evening sky, but you'll have to wait until dawn draws near to witness several other intriguing sights.

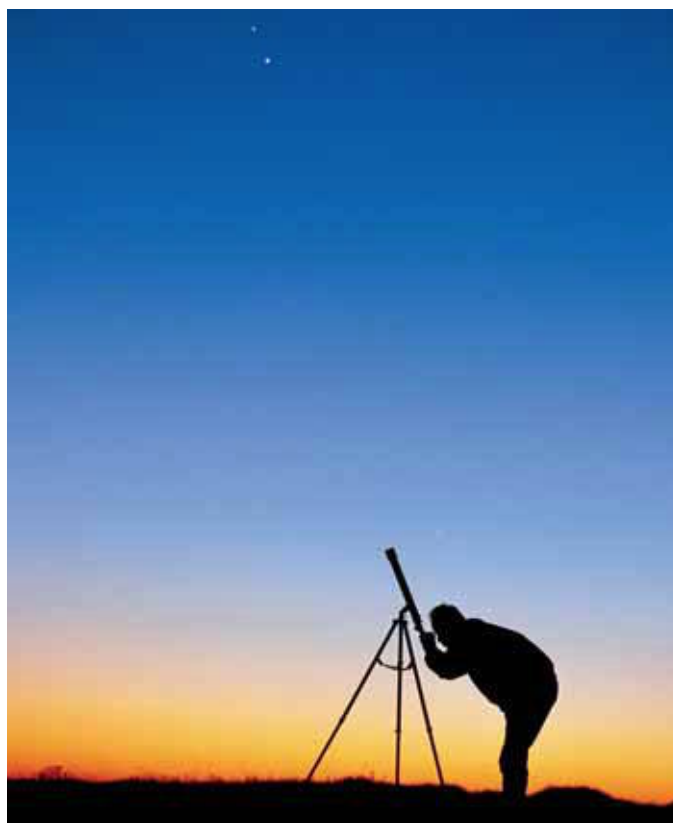
The ringed world returns

Guaranteed to draw gasps of delight from first-time observers, a telescopic view of Saturn and its rings stands without compare. The smallest scope easily reveals the tipped rings artfully surrounding a central globe. Perfection comes to mind: If the rings were either closer in or farther out, they somehow would look out of proportion to the planet. ☾ To find Saturn, look east in

the late evening for the bright “star” with a steady yellow glow. Bump up the magnification as much as possible while still getting a clear, steady view. Saturn really comes to life this month because the planet casts a shadow onto the rings, giving the system an unmistakable three-dimensional appearance.

A 2-inch scope reveals a starlike dot outside the rings, but it's more than what meets the eye. This is Saturn's moon, Titan, the second-biggest moon in the solar system. During a 2-week period, you can watch this nearly Mars-sized moon complete an orbit of its beautiful home world.

If you're a keen observer, set your alarm for an hour before dawn — the remainder of the bright planets put on quite a show for early risers. You can't miss Jupiter and Venus paired low in the east. Blazing white Venus is descending slowly from her throne as the morning star and will pass one Moon-width above Jupiter November 4. The sight of the two brightest planets next to



VENUS AND JUPITER meet in the morning sky this month, stirring memories of this spectacular evening conjunction in February 1999. LARRY LANDOLFI

each other will be well worth the effort to get up early. Jupiter appears the fainter of the two, but it still shines

brightly with a steady, light-peach hue.

Below the two planets and tucked against the horizon,

you'll find the blue-orange pair of Spica and Mars. Mars currently lies on the far side of the Sun from Earth, so it appears tiny and faint, no rival for the stellar sparkle of Spica.

The month's top event happens the morning of November 9, when the Moon swallows Jupiter. This occultation takes place in broad daylight, around 11 a.m. EST, so take your telescope to work if you want to watch. An 8-inch scope will reveal the four bright jovian moons as well. Unless you're really lucky, such events are rare. Observers east of the Mississippi River have a chance to see Jupiter occulted both this month and next, but people in California won't get to see this happen until 2016.

If you live in parts of Australia or New Zealand, you'll miss the Jupiter event but get a bigger prize: The Moon occults Venus on the morning of the 10th and then, one day later, passes in front of Mars.

The roar of the Leonid meteor shower these past few years has settled down to its more typical purr. If you're new to meteor observing, you may want to wait until next month's more active Geminid shower. At the peak of this year's Leonids — shortly before dawn Wednesday, the 17th — expect about 10 shooting stars per hour.

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70 · 90 · 105 · 125

\$50 REBATE*!

ETX-90[™], 105[™] and 125[™]
* See page 7 for details

**Hurry! Offer Ends
Oct. 31, 2004!**

Just because a star may be millions of years old, doesn't mean it should take you that long to find it!

Serious astronomers for years have flocked to the Meade[®] ETX for its combination of observatory-quality optics and its precise AutoStar object finding capabilities – all in an easy-to-use, ultra-portable package. Want to see a hard-to-find, deep space galaxy? Push a button. Same goes for planets, stars, nebulae and more. With the Meade ETX you don't need star charts, geometry or an advanced degree. Just pick an object you want to see, press a button, and AutoStar will automatically point your telescope to the selection. Don't know what you want to see this evening? Just go to the "Tonight's Best[™]" menu and AutoStar will recommend the best objects in the sky for that particular time and location from its database of over 30,000 celestial objects. All you need is a clear night, a dark sky, and a little bit of curiosity. Whether you already know the sky by heart, or are just beginning your journey of discovery, your Meade ETX will take you where you want to go.

Diffraction-Limited Optics: The ETX Maksutov-Cassegrain optics are so crisp in contrast, brightness and image resolution that they outperform many telescopes of larger aperture. *Sky & Telescope*[®] magazine described the ETX-90 optics as "excellent...stellar diffraction patterns were virtually textbook-perfect." All ETX Maksutov-Cassegrain optics are made in the USA at Meade's state-of-the-art manufacturing facility in Irvine, California.

AutoStar EasyAlign[™]: All ETX models feature Meade's patented Level-North Technology (LNT[™]). EasyAlign/LNT revolutionized amateur astronomy by solving the stargazer's two biggest challenges:

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Sturdy Field Tripod: Constructed of strong, lightweight steel, it provides a rigid mounting platform for virtually any observing or photographic application. Tripod height is adjustable, and can be set up in either equatorial or altazimuth position.

SPECIFICATIONS AND PRICES

Model	ETX-70AT	ETX-90AT	ETX-105AT	ETX-125AT
Optical Design	Achromatic refractor Maksutov-Cassegrain	Maksutov-Cassegrain	Maksutov-Cassegrain	Maksutov-Cassegrain
Aperture	70mm (2.8")	90mm (3.5")	105mm (4.13")	127mm (5.0")
Focal Ratio	f/5	f/13.8	f/14	f/15
Focal Length	350mm	1250mm	1470mm	1900mm
Primary Mirror	N/A	Pyrex [®] Glass	Pyrex [®] Glass	Pyrex [®] Glass
Correcting Lens	N/A	BK7 Optical Glass	BK7 Optical Glass	BK7 Optical Glass
Autostar Controller	Autostar (#494)	Autostar (#497)	Autostar (#497)	Autostar (#497)
Tripod	#882 Field Tripod	#884 Field Tripod	#884 Field Tripod	#884 Field Tripod
Price	\$299	\$595	\$795	\$995
Shipping & Handling	\$ 20	\$ 30	\$ 35	\$ 40
UHTC[™] *	Not available	\$ 50	\$ 75	\$ 90

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* Meade Ultra-High Transmission Coatings group must be ordered at the time of telescope purchase. The UHTC cannot be retrofitted.



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LX200GPS
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THE OPTICAL STANDARD

For over three decades, **Meade® Instruments** has led the development of astronomical equipment through engineering innovations that have changed the way amateur astronomers view and photograph the night sky.

Meade's engineering team (the largest in the industry) meticulously designs and engineers the highest quality optics, precision mechanics, and advanced electronics into every telescope we manufacture. We don't go to these lengths just to stay number one — we do it because astronomy is our passion.

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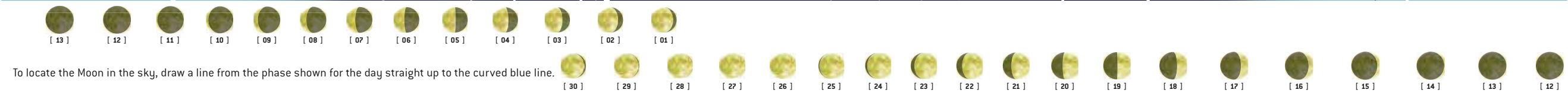
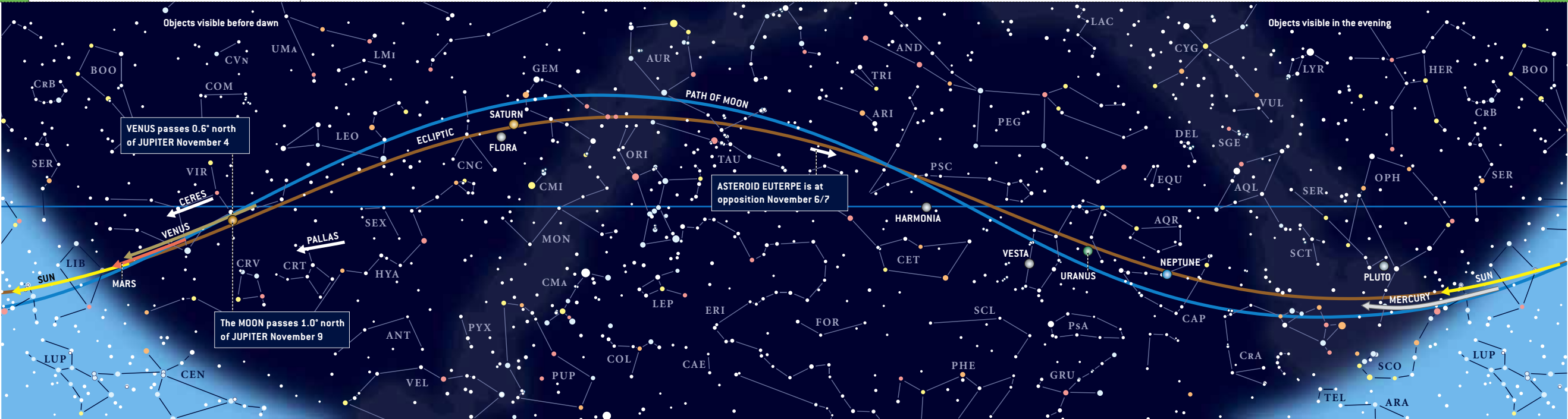
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Manufactured under U.S.
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6,392,799 and
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the U.S.A. and
worldwide.

14" LX200GPS-SMT

Planets this month

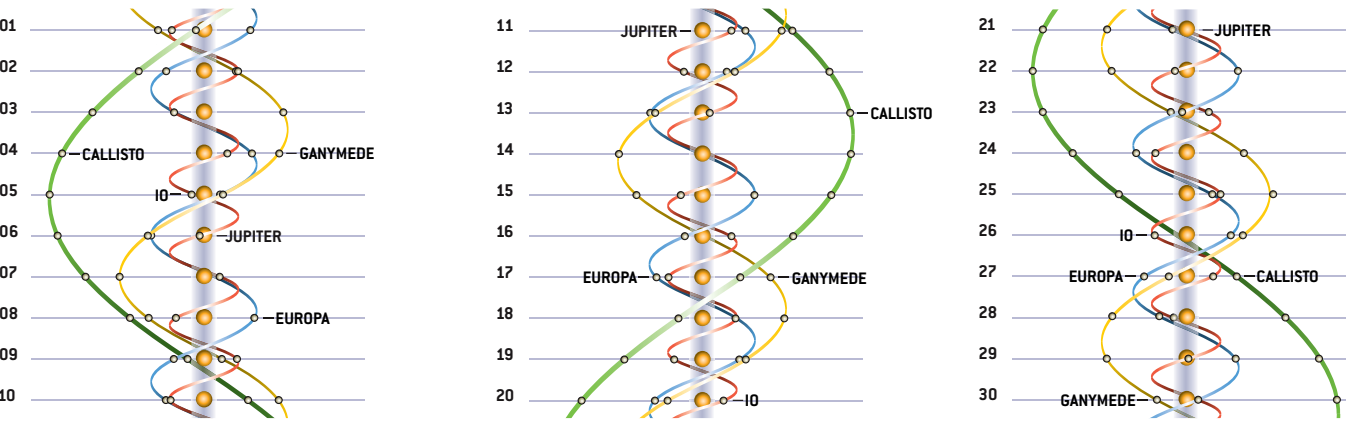
This map unfolds the entire night sky from sunset [at right] until sunrise [at left]. Arrows and colored dots show motions and locations of solar system objects during the month.



PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	November 15	November 30	November 15	November 15	November 15	November 15	November 15	November 15	November 15
Magnitude	-0.3	0.3	-4.0	1.7	-1.7	0.0	5.8	7.9	14.0
Angular Size	5.9"	8.2"	12.6"	3.7"	32.1"	19.4"	3.5"	2.3"	0.1"
Illumination	76%	33%	84%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.136	0.817	1.323	2.509	6.139	8.581	19.862	30.227	31.733
Distance (AU) from Sun	0.419	0.337	0.719	1.619	5.451	9.053	20.056	30.067	30.872
Right Ascension [2000.0]	16h49.6m	17h45.3m	13h18.9m	14h01.9m	12h40.0m	7h52.1m	22h20.2m	21h00.7m	17h22.8m
Declination [2000.0]	-25°02'	-24°54'	-6°24'	-11°47'	-3°04'	20°37'	-11°12'	-17°05'	-15°00'

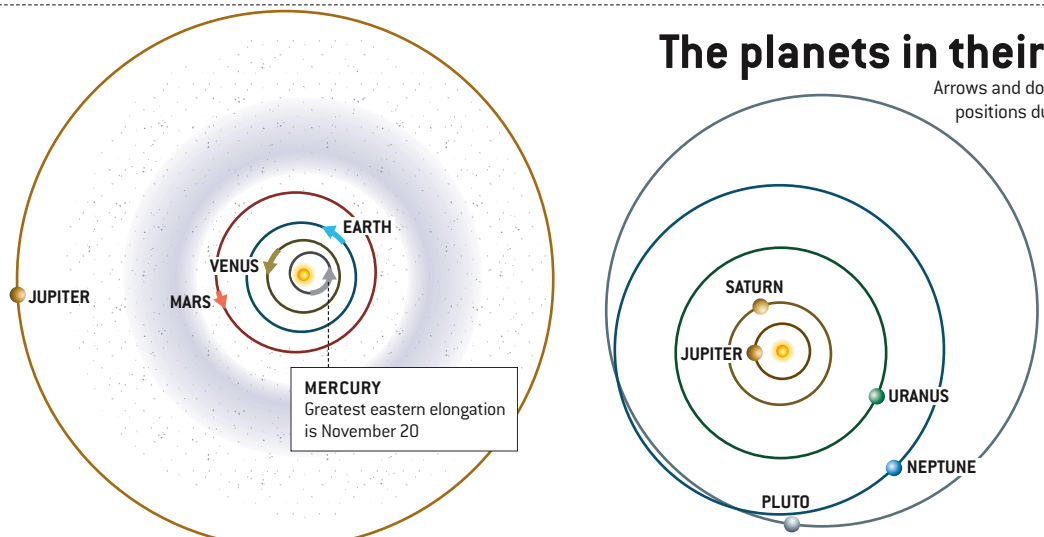
Jupiter's moons

Dots display positions of Galilean satellites at 5 A.M. EST on date shown. South is at top to match the view in a telescope.



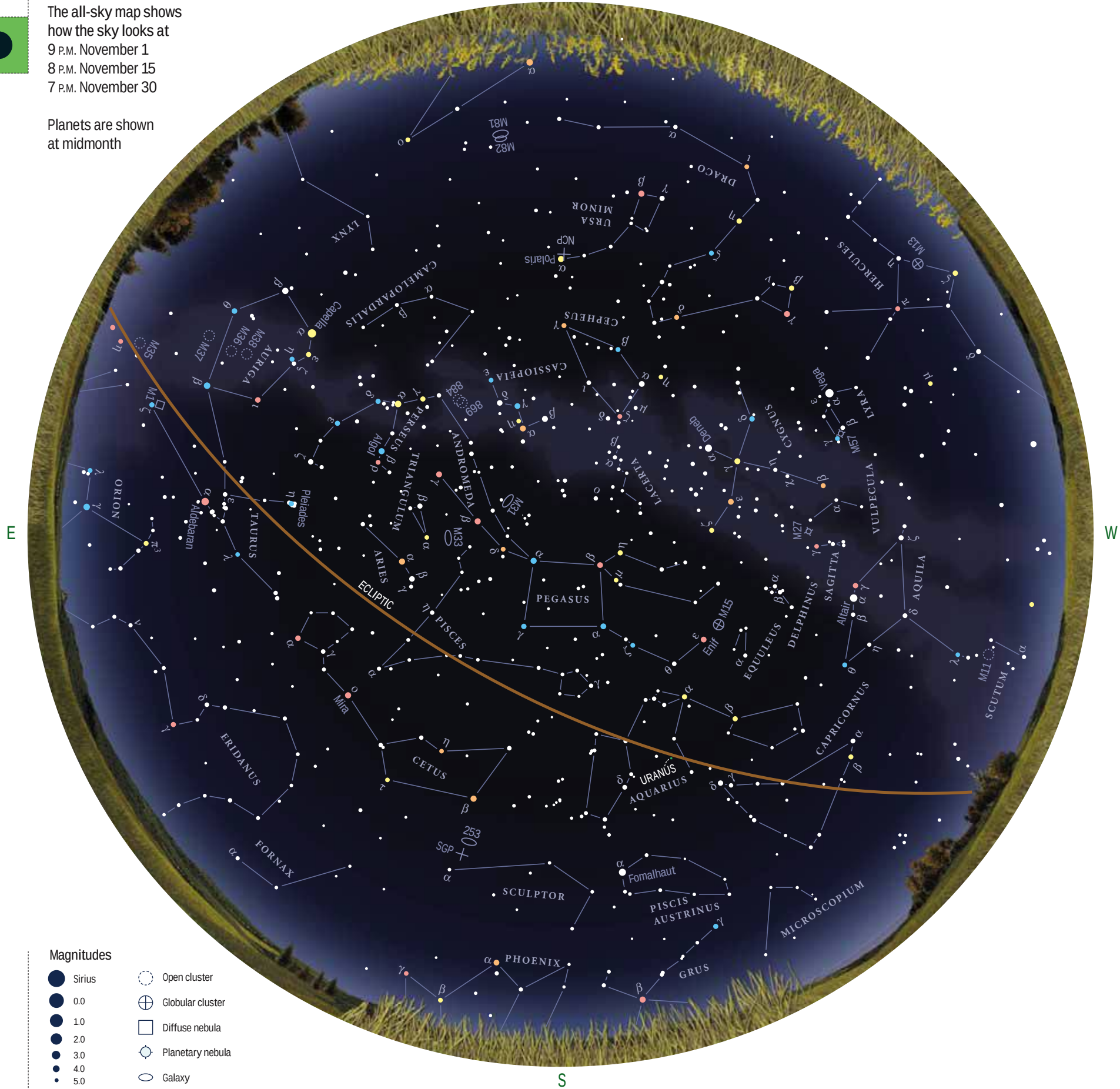
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
9 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth



Magnitudes

- Sirius
- Open cluster
- 0.0
- ⊕ Globular cluster
- 1.0
- Diffuse nebula
- 2.0
- Planetary nebula
- 3.0
- Galaxy
- 4.0
- 5.0

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

november 04

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						
	[01]	[02]	[03]	[04]	[05]	[06]
						
[07]	[08]	[09]	[10]	[11]	[12]	[13]
						
[14]	[15]	[16]	[17]	[18]	[19]	[20]
						
[21]	[22]	[23]	[24]	[25]	[26]	[27]
						
[28]	[29]	[30]				

- 02 The Moon is at apogee (251,654 miles from Earth), 1:08 P.M. EST

03 The Moon passes 5° north of Saturn, 3 P.M. EST

04 Venus passes 0.6° north of Jupiter, 4 P.M. EST

05 Last Quarter Moon is at 12:53 A.M. EST

06 Asteroid Euterpe is at opposition, 11 P.M. EST

08 Saturn is stationary, 6 A.M. EST

09 The Moon passes 1.0° north of Jupiter, 11 A.M. EST

The Moon passes 0.2° south of Venus, 9 P.M. EST

10 The Moon passes 0.5° south of Mars, 11 P.M. EST

11 Mercury passes 2° north of Antares, 5 A.M. EST

12 New Moon is at 9:27 A.M. EST
- 13 The Moon passes 0.9° south of Mercury, 10 P.M. EST

14 The Moon is at perigee (225,130 miles from Earth), 8:54 A.M. EST

16 Venus passes 4° north of Spica, 4 A.M. EST

17 Leonid meteor shower peaks

The Moon passes 5° south of Neptune, 10 P.M. EST

19 First Quarter Moon is at 12:50 A.M. EST

The Moon passes 4° south of Uranus, 8 A.M. EST

20 Mercury is at greatest eastern elongation (22°), 8 P.M. EST

26 Full Moon is at 3:07 P.M. EST

30 The Moon is at apogee (252,248 miles from Earth), 6:23 A.M. EST

The Moon passes 5° north of Saturn, 9 P.M. EST

10 REASONS WHY YOU SHOULD BUY A MEADE® SCHMIDT-CASSEGRAIN:

1. Meade Ultra-High Transmission Coatings (UHTC™) Group increases total light transmission and image brightness by nearly 20% over Meade's standard coatings. Objects such as stars, galaxies and nebulae will appear significantly brighter.
MEADE EXCLUSIVE

2. State-of-the-Art Optical System
Water white glass is standard equipment in all 8", 10", 12" and 14" Schmidt-Cassegrain corrector lenses. Water white glass delivers an increase of light transmission in excess of 10% as compared to competing Schmidt-Cassegrain telescopes using green soda lime glass.
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3. Zero Image-Shift Microfocuser allows you to obtain precise image focus with no image movement.
MEADE EXCLUSIVE

4. Primary Mirror Lock locks the mirror in place during long-exposure photography.
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5. Oversized Primary Mirror diameters are greater than their listed aperture (e.g., the diameter of the 8" LX200™GPS is actually 8.25"). This additional 1/4" yields a wide, fully illuminated field-of-view. The result is that Meade's Schmidt-Cassegrains have brighter off-axis field illuminations (aperture-for-aperture) than competing Schmidt-Cassegrain telescopes using non-oversized mirrors.
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6. Smart Drive™ provides permanent periodic error correction (PPEC) on both axes by learning and averaging error over the course of one or more training periods, thereby minimizing guiding corrections during long-exposure photography. PPEC is available on both axes and functions in polar and altazimuth modes.
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7. Sony® GPS Receiver and True-Level Sensor automatically inputs precise time, date, and geographical location to help quickly and precisely align and level the telescope.
MEADE EXCLUSIVE

8. Smart Mount™ constantly refines pointing accuracy each time an object is centered and updated. Compatible with both equatorial and altazimuth mounts.
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9. AutoStar® II controller features "Hot Keys" for quick access to a 145,000 celestial object database. AutoStar II can be updated with the latest software upgrades, guided tours and timely objects like comets free at meade.com.
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10. AutoStar Suite™/LPI™ allows even novice stargazers to capture and process stunning images of the Moon, Saturn, Jupiter... and more.
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OPTICAL DESIGN	SCHMIDT-CASSEGRAIN					MAKSUTOV-CASSEGRAIN
APERTURE	8"	10"	12"	14"	16"	7"
FOCAL RATIO	F/10	F/10	F/10	F/10	F/10	F/15
FOCAL LENGTH	2000MM	2500MM	3048MM	3556MM	4064MM	2670MM
CORRECTOR LENS	WATER WHITE	WATER WHITE	WATER WHITE	WATER WHITE	BK7	BK7
PRIMARY MIRROR	PYREX®	PYREX®	PYREX®	PYREX®	PYREX®	PYREX®
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SHIPPING & HANDLING	\$105	\$145	\$215	\$265	\$385	\$125
UHTC (OPTION ONLY AT TIME OF ORDER)	\$175	\$235	\$295	\$350	\$495	\$150
LPI/AUTOSTAR SUITE (\$149 VALUE)	FREE	FREE	FREE	FREE	FREE	FREE

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- Micrometric X-Y positioning of the reticle within the field
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- Wireless red LED illuminator with adjustable brightness control
- Multi-coated optics
- Rubber eyecup
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- Internal batteries included

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- State-of-the-art digital technology with crisp, contrast-rich images
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- Ergonomic compact design
- Includes tripod adapter; case; AC power supply; red, green and neutral density eyepiece filters to optimize your view

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Barlow Lenses

Series 4000 #140 2x Barlow Lens (1.25")

- Fully color-corrected apochromatic design
- 3-element multi-coated, air spaced optics
- Double the eyepiece power
- Crisp, high contrast images

Clear aperture 26mm \$79.95 (5.26)

2x Short-Focus Barlow Lens (1.25")

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- Use with Meade ETX telescopes
- Insert star diagonal into it for 3x

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2" Diagonal Mirrors with UHTC™

- Precision-polished flat mirror
- UHTC-coated (95%+ reflectivity)
- Includes 1.25" eyepiece adapter
- #929 threads on to the rear cell of most SCTs
- #930 slides into any 2" focuser

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\$119.95 (6.85)



9x63 Roof Prism Binocular

- Large 63mm aperture fully multi-coated objective lenses and BAK-4 roof prisms deliver bright images, perfect for surveying the constellations and observing nebulae and comets
- Multi-coated long eye-relief, wide apparent field eyepieces are fitted with comfortable rubber eyecups
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- Equatorial wedge for 8" LX90 **\$169.95 (20.00)**
- Standard equatorial wedge: use with Meade's 7" MAK and 8" SCT LX-series telescopes **\$149.95 (20.00)**
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f/6.3 Focal Reducer/Field Flattenor

- 4-element, multi-coated
- Threads onto the rear cell of most SCTs
- Converts f/10 scopes to f/6.3 or f/6.3 SCTs to f/4
- Visual field is increased by 56%
- Reduces exposure times by about 50%

41mm clear aperture \$129.95 (5.26)



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- Increased edge-of-field resolution and color correction
- Reduces CCD exposure times by up to 80%
- Threads onto the rear cell of most SCTs
- Variable T-adaptor (included): f/3 and f/5 on f/10, 1.9 and f/3.2 on f/6.3
- Not for visual applications

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- Dramatically reduces vibration-damping time
- Recommended by top astronomers for any telescope

Set of 3 \$49.95 (7.02)



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- Flip mirrors greatly facilitate precise centering for CCD imaging
- Both #644 and #647 model Flip Mirrors incorporate a flexure-free one-piece body design, locking threaded helical focuser for the eyepiece, precision-polished UHTC-coated mirror diagonal flats, precision X/Y adjustment mechanism for the diagonal mirror with locks for precise centering, and multiple rotating adapters for T-thread and 1.25" O.D. camera attachment
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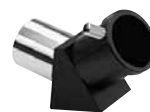
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- 45° design facilitates a comfortable viewing angle for extended reticle within the field
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Model #928 for any SCT or refractor telescope focuser that accepts 1.25" O.D. accessories **\$42.95 (3.86)**
 Model #932 for ETX-90™, 105, and 125 model telescopes **\$49.95 (3.86)**



#928



#932



ETX® Hard Carrying Cases

- Convenient for storage or travel
- Hard plastic box lined with die-cut foam
- Multiple storage areas for accessories

#774 for ETX-90™ models \$99.95 (8.58)
#776 for ETX-105™ models \$99.95 (8.58)
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Series 4000 8mm-24mm Zoom Eyepiece

- 7-element, fully multi-coated optics (1.25")
- 55° apparent field of view at 8mm
- Internal zoom design, with graduated scale in 1mm units
- Performance is fully consistent with the finest fixed-focal length eyepieces

\$219.95 (6.38)



Filters

Series 4000 Photo-Visual Color Filters

- Large, 26mm aperture, anti-reflection coated
- Filter is pure crown glass, dyed-in-the-mass
- Threads onto most 1.25" eyepieces
- Increases contrast of fine planetary features

Set #1: #12, #23A, #58, #80A \$49.95 (4.54)
Set #2: #11, #25A, #47, #82A \$49.95 (4.54)
Set #3: #8, #21, #38A, #56 \$49.95 (4.54)

* Individual filters may be purchased separately for **\$14.95 (2.73)**



Series 4000 Moon Filter

- Reduces glare and irradiation during lunar observing
- 13% uniform light transmission across the visual spectrum
- Threads into 1.25" barrels

\$16.95 (2.73)

Series 4000 Nebular Filters

- Premium multi-layer interference filters
- Broadband filters are great for all types of deep sky observing, and will block most forms of light pollution
- #908B:** Threads into 1.25" eyepieces, 26mm diameter **\$79.95 (4.54)**
- #911B:** Threads on to the rear cell of most SCTs, 36mm diameter **\$99.95 (5.26)**
- Narrowband filters yield spectacular high contrast views of faint nebulae, and work in heavily light-polluted conditions
- #908N:** Threads into 1.25" eyepieces, 26mm diameter **\$89.95 (4.54)**
- #911N:** Threads on to the rear cell of most SCTs, 36mm diameter **\$119.95 (5.26)**



#911B

#908B

Series 4000 Oxygen-III Filters

- Exclusive Meade 60-layer interference coating gives incredible O-III transmission performance
- Observe diffuse emission, planetary nebulae and supernova remnants
- Isolate the 496nm and 501nm O-III lines
- #908X:** Threads into 1.25" eyepieces, 26mm **\$99.95 (4.54)**
- #911X:** Threads on to the rear cell of most SCTs, 36mm diameter **\$149.95 (5.26)**



#911X

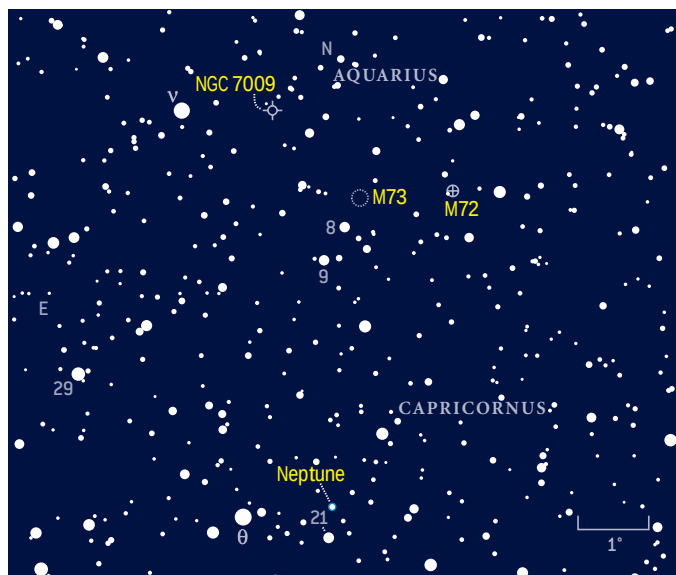
#908X

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THE DEEP SKY

When dying stars puff off their outer layers, they create glowing clouds of gas that many deep-sky observers rank among their favorite targets.



A planetary delight

It probably won't come as a big surprise, but when seen through a small telescope, a planetary nebula often looks a lot like a planet. In the 1700s, Charles Messier cataloged the first few of these celestial puff-balls. Then along came William Herschel, the godfather of deep-sky observers. Only 1 year after his 1781 discovery of Uranus, which appeared as a small, round, greenish disk in his 6-inch reflector, he began sweeping up other small, round disks. Their similar size, shape, and color to the newest planet made their classification obvious: planetary nebulae.

The first object in this new category was the Saturn Nebula

in Aquarius. In Herschel's own words, it appeared "very bright, nearly round, planetary, not well defined disk. 25 arcseconds." For comparison, the ball of Saturn appears some 15" to 20" across from Earth.

With a scope 8 inches in aperture or less, you'll see the Saturn Nebula just like Herschel did. Interestingly, neither Herschel nor his son John, also a high-caliber observer, saw the tendrils that are still referred to by their Latin name, "ansae."

In 1849, using his "Leviathan" telescope, Lord Rosse first saw these extensions sticking off opposite edges of the disk and named the object the Saturn Nebula. Today, with a high-quality eyepiece on a well-made 10-inch telescope (a mere tip of the hat to Rosse's massive, 6-foot-wide mirror), you can begin to see the ansae at powers above 200x.

In the 1880s, after thousands more deep-sky objects had been discovered, astronomer John Dryer compiled a huge reference called the *New General Catalogue of Nebulae and Clusters of Stars*, or NGC. The Saturn Nebula made it at number 7009, where it earned three exclamation marks in its brief description.

After viewing the nebula, aim your scope 6° to the south and have a look at Neptune. This real planet has the same brightness, 8th magnitude, as the nebula but appears almost a factor of 10 smaller through the eyepiece. Bump the power past 150x and look for a "fat" star, and you'll see the planet's tiny, blue-gray disk.

A planetary nebula forms at the end of a Sun-like star's life. As the star exhausts its nuclear fuel, it swells to become a red giant and eventually sheds its outer layers. The stellar core contracts into a white dwarf, which emits lots of ultraviolet radiation. This energetic radiation ionizes the atoms in the surrounding cocoon, and they glow with specific colors. (This means they respond well to nebula, or "light pollution," filters.) Many planetaries have a high surface brightness, so they can punch through a city's veil of light pollution or the glare from a Full Moon.

A quaint pair

Most observers describe well-known deep-sky objects with superlatives, but the wide pair

of M72 and M73 belongs in a class by itself — and not a higher class. M72 is a distant globular cluster, while M73 is simply a group of four stars.

Tucked away among the rich but faint starfields of western Aquarius, M72 lies just 3° southwest of the Saturn Nebula. It shows up in a low-power, rich-field telescope as a small, fuzzy cotton ball glowing at magnitude 9.3. A 6-inch scope at high power from a dark site will pick up a few of the cluster's red giants, giving it a granular appearance.

Pan 1° east of the globular and you'll find M73. At times, this object dissolves into the background. It consists of four stars, glowing between magnitudes 10 and 12, in a triangular shape. Through his relatively primitive telescope, Messier saw it as "a cluster of 3 or 4 small stars which resembles a nebula at first sight, containing a little nebulosity." The superior optics of today's scopes reveal no trace of nebulosity.



THE SATURN NEBULA (NGC 7009) in Aquarius is a planetary nebula whose ejected gas forms a disk shape reminiscent of the ringed planet. DALE MAIS

Martin Ratcliffe is former president of the International Planetarium Society. Alister Ling is a meteorologist for Environment Canada.



THE PLANETS

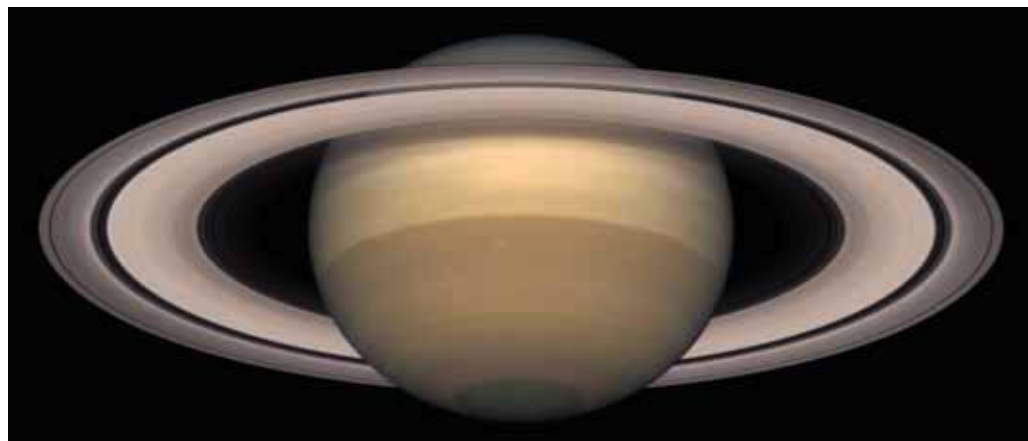
Saturn climbs high in the sky after midnight, heralding a magnificent conjunction between Venus and Jupiter in the hours before dawn.

November begins with a spectacular predawn pairing of the two most prominent planets. Venus, the brightest, meets Jupiter, the largest, in a close conjunction. Added drama occurs when the Moon occults Jupiter for observers in the eastern United States and Canada. Uranus and Neptune remain on fine view in the evening sky, while later, Saturn rises to add majesty to the night sky.

Innermost Mercury reaches greatest eastern elongation November 20, although it will not be easy to find. It lies on a part of the ecliptic — the apparent path of the Sun and planets across our sky — that currently forms a shallow angle to the western horizon after sunset. Although Mercury lies 22° from the Sun at greatest elongation, it appears only 5° above the southwestern horizon half an hour after sunset. It shines brightly, however, at magnitude -0.3, so sharp-eyed observers will find it if they have a clear, flat horizon toward the southwest.

Once Mercury sets, turn your attention to Uranus and Neptune. You'll need binoculars or a telescope to spy Neptune, and a star map that reaches at least 8th magnitude to home in on its location. (See page 63 for a finder chart showing the planet's position in mid-November.)

Neptune lies near the center of the inconspicuous constellation Capricornus, which hangs



SATURN SHINES in all its glory in November's morning sky. NASA AND THE HUBBLE HERITAGE TEAM (STScI/AURA)

in the south as darkness falls. The challenge for many of us is that few of the guide stars in Capricornus can be seen from a street-lit neighborhood. But don't despair. A pair of 3rd-magnitude stars usually shows up. Algedi (Alpha [α] Capricorni) and Dabih (Beta [β] Cap) lie five Moon-widths apart in the constellation's northwestern corner. From there, slide southeast until you reach 4th-magnitude Theta (θ) Cap in the north-central part of the group. Then use the finder chart to locate Neptune west-northwest of Theta. The planet glows at magnitude 7.9 and shows a 2.3"-diameter, blue-gray disk through a telescope.

Uranus proves to be an easier target because it's brighter and lies higher in the evening sky. Glowing at magnitude 5.8, the planet pops into view in binoculars, even from moderately light-polluted sites. Look for it in Aquarius

the Water-bearer nearly due west of Sigma (σ) Aquarii and south of Theta Aqr. The planet stays nearly fixed relative to the background stars during the month. Through a telescope, Uranus displays a disk 3.5" in diameter sporting a distinct blue-green hue.

Beautiful Saturn stands clear of the eastern horizon by 11 p.m. local time in early November. On the 3rd, a gibbous Moon rises with Saturn, separated by 7°. The two stage a repeat performance November 30, when they rise together around 8 p.m. This time, the two appear 5° apart.

Saturn lies in Gemini the Twins south of the two 1st-magnitude stars, Castor and Pollux, that dominate the constellation. Saturn appears noticeably brighter than both of them at magnitude 0.0. The rings, recently photographed in remarkable detail by the Cassini spacecraft, show up easily from Earth in any tele-

scope. The dark and relatively empty Cassini Division separates the outer A ring from the brighter B ring. A good 6-inch or larger scope might reveal the dusky, innermost C ring.

Most telescopes also show a number of moons surrounding Saturn. The brightest is Titan, which glows at magnitude 8.3. The Cassini spacecraft flies past this moon both October 26 and December 13. Earthbound observers can spot Titan most anytime, although it's easier to pick out when it passes due north or south of the planet. The moon lies north of Saturn November 12/13 and 28/29 and south November 4/5 and 20/21.

A number of smaller moons closer to Saturn scurry around the planet like fireflies. Faintest is the innermost major moon, Mimas, which glows at magnitude 12.9. Enceladus, a February 2005 target of the Cassini spacecraft, glows one magnitude brighter. Three

Saturn on November 18, 4 A.M. EST



THE MOON OCCULTS JUPITER during daylight November 9 for observers in eastern North America. LEE C. COOMBS

10th-magnitude moons — Tethys, Dione, and Rhea, in order of increasing distance from Saturn — can be seen in almost any telescope.

Enigmatic Iapetus reaches greatest western elongation November 17/18, when it glows its brightest, magnitude 10.1. One hemisphere of Iapetus reflects lots of light while the other appears dark, so the moon's brightness fluctuates as it orbits the planet. Iapetus passed north of Saturn at the end of October and spends the first 2 weeks of November brightening as it heads toward western elongation. It orbits far from Saturn, appearing almost 10' (about 13 ring diameters) from the planet at its brightest.

With Saturn still gleaming high in the south, the main action shifts to the predawn sky. Venus and Jupiter dominate the early morning scene. Venus shines at magnitude -4.0 , and by 5 a.m. local time November 1, it's unmistakable above the eastern horizon just as the first embers of dawn become noticeable. Jupiter rises 20 minutes after Venus and lies just 4° below its companion. Although fainter than Venus, Jupiter still dazzles at magnitude -1.7 . This graceful pair lies in the constellation Virgo the Maiden, slightly west of the 3.7-magnitude star Porrima (Gamma [γ] Virginis).

Watch during November's first week as Venus slides past Jupiter. For North American

observers, the two appear closest the mornings of November 4 and 5. On the 4th, observers on the West Coast will see Venus standing 0.7° above Jupiter an hour before sunrise. The following morning, November 5, East Coast observers will see the pair side by side and slightly closer, with 0.6° separating them. Every morning thereafter, Venus continues to fall toward the horizon relative to Jupiter, and their separation increases by about a degree per day.

During daylight November 9, observers east of a line from Saskatchewan to Florida will see a thin crescent Moon pass in front of Jupiter. In Boston, the occultation starts at 11:06 a.m. EST with the pair high in

the southwest. Residents of Atlanta will see Jupiter disappear at 11:24 a.m. EST, while those in Chicago will see the event begin at 9:57 a.m. CST. Visit www.lunar-occultations.com/iota/iotandx.htm for times at other locations. Set up at least half an hour before the event to make sure you can locate the Moon and Jupiter.

Mars makes a brief appearance in the eastern sky before dawn. Although still far from Earth and not particularly prominent, Mars has begun its long trek to a nice opposition in late 2005. On November 30, the Red Planet stands 3° below Venus in the growing twilight. Mars appears as a moderately bright, ruddy "star" shining at magnitude 1.7.



METEORS AND MOONS

The Moon doesn't interfere with this year's Leonid meteor shower. Despite not being able to see the Cassini spacecraft, you can view a lunar crater named for the same person.

A purring Lion

Recent years have shown enhanced activity for the Leonid meteor shower, but none is predicted for this year's return. The shower peaks the morning of November 17, and reduced numbers can be seen from November 14–21. Observers may catch a meteor every few minutes under the best conditions. However, following the storm-level rates in recent years, the actual number is hard to predict and could be high for certain regions of the world. Best views of the shower come once the radiant — located in the constellation Leo the Lion — has climbed high in the sky, after 3 a.m. Fortunately, the waxing crescent Moon sets well before midnight November 16.

The minor northern Taurid meteor shower peaks November 11/12. Because this is the same day as New Moon, conditions couldn't be better. The

shower and its cousin, the southern Taurids (which peak November 4/5), derive from debris left behind by Comet 2P/Encke, the comet with the shortest known period. The radiant remains visible most of the night, but rates tend to be low. However, the shower produces occasional fireballs, so it doesn't hurt to keep an eye on it.

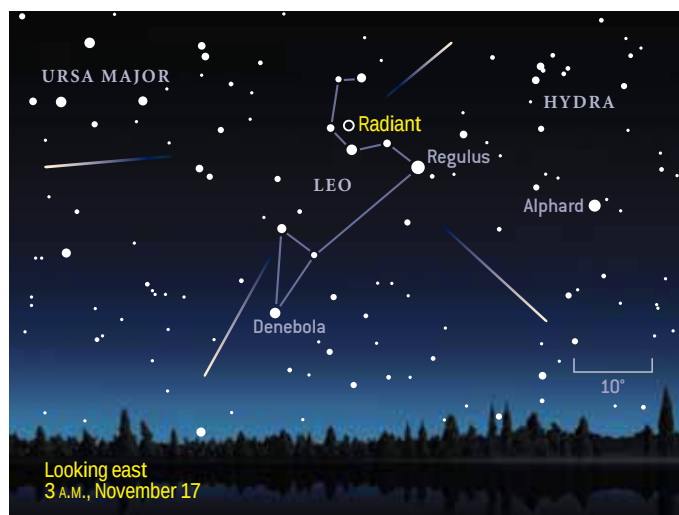
Cassini's lunar tribute

With a spacecraft carrying the name of the famed Italian-born French astronomer Giovanni Cassini, it seems appropriate to highlight a lunar feature bearing the same name. (Although the crater takes its name from both Giovanni and his son, Jacques.) First recorded on a lunar map dating to 1692, Cassini stands as one of the more unusual craters on the Moon. The 35-mile-wide crater lies northeast of Archimedes and southeast

of Plato in the easternmost region of Mare Imbrium close to the lunar Alps.

Two large craters — called Cassini A (10.5 miles across) and Cassini B (5.5 miles across) — dominate the main crater's floor. Under low lighting conditions, you also may spot the tiny crater that lies just inside the northern wall. A fresh crater resembling Cassini B lies on the outer ramparts

northwest of the main crater. Lava fills the main crater's floor almost to the top of the wall, especially at the southern end. A pair of short rilles occupies the space between Cassini A and the eastern wall of the main crater. These are best seen a few days after the Sun rises over the crater, an event that occurs when the Moon is 8 days old. This month, that comes November 19.



THE CRATER CASSINI (arrow) and its two smaller, embedded craters sit on the eastern shore of Mare Imbrium, just southeast of the lunar Alps.

FROM THE CONSOLIDATED LUNAR ATLAS (LPL/JA)

COMETS AND ASTEROIDS

While a bright comet sails the morning sky, a few more challenging ones navigate the dead of night. Also, watch a faint asteroid take out a bright star.



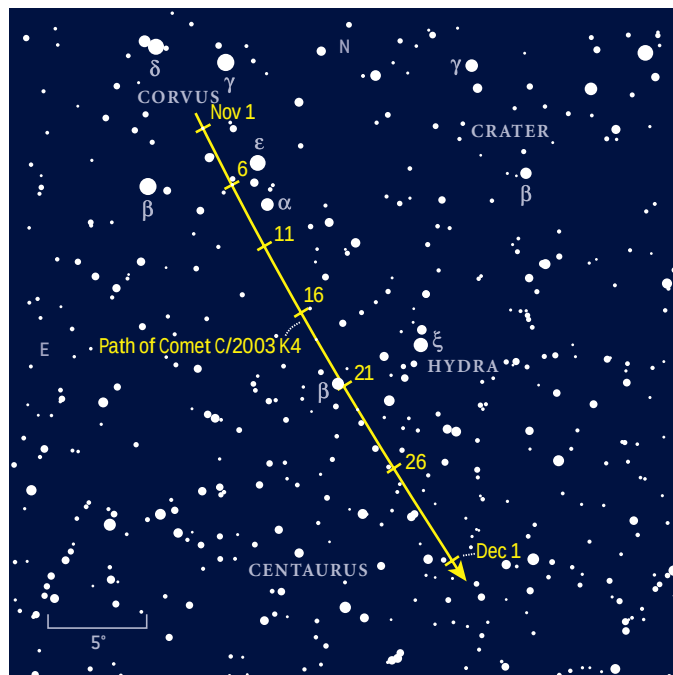
COMET C/2003 K4 should reach 5th magnitude this month, providing a worthy observing target in the predawn hours. GERALD RHEIMANN AND MICHAEL JÄGER

Sinking south

After plunging behind the Sun in October, Comet C/2003 K4 (LINEAR) reappears in the morning sky. It should glow around 5th magnitude, putting it well within range of binoculars from a city backyard. Throughout November, the comet remains low in the gathering dawn as it continues to journey south, becoming well-placed for observers south of the equator.

C/2003 K4 will appear best if you have a clear horizon to the southeast. The comet starts off in the middle of Corvus the Crow, well below Leo and to the lower right of Venus and Jupiter. If you're out watching the planetary conjunction on the 5th, take a few minutes to observe the comet. The Last Quarter Moon won't interfere much. A look through

a telescope reveals the comet's condensed central region and stubby tail, which lies nearly parallel to the horizon.



If you can't wait until morning, or don't like to get up early, three comets come within reach of 10-inch scopes after dusk. C/2001 Q4 (NEAT), that nice spring comet, slices through Draco's neck not far from the Cat's Eye Nebula (NGC 6543). At 12th magnitude, Q4 is not for the faint of heart. Almost as hard to find is 12th-magnitude C/2003 T4 (LINEAR). It also lies in Draco, floating across the primary star-hopping route to the Splinter Galaxy (NGC 5907). Periodic comet 78P/Gehrels 2 arcs to the southwest of the Pleiades star cluster.

An asteroid dance

Regular readers won't be surprised to find that asteroids 4 Vesta and 9 Metis continue

to arc together through southern Aquarius. At magnitude 7.4, Vesta is pretty easy to follow through binoculars. It lies about one field of view below the wide triplet Psi¹ (ψ^1), Psi² (ψ^2), and Psi³ (ψ^3) Aquarii. Metis proves a lot tougher because it glows at magnitude 10.2, significantly fainter than the planet Neptune.

Hide in plain sight

Despite the number of aircraft in the sky, it's not that common for their shadow to sweep across you — you have to be in the right place at the right time. Asteroids suffer the same fate. With a little bit of planning and a decent dose of luck, however, you can stand in the shadow of a space rock as it briefly blocks the light from a distant star.

The International Occultation Timing Association (IOTA) makes predictions for and analyzes data from asteroid occultations. Their web site www.lunar-occultations.com/iota/iotandx.htm contains shadow paths and times for events around the world. Any one place typically has a couple good chances a year. A cool event runs along a thin band from Texas to Maine around 9:30 p.m. EST November 5, when an 18th-magnitude asteroid hides 4.7-magnitude Lambda (λ) Aquarii. Just after 11 p.m. EST on the 28th, asteroid 1698 Christophe blots out 6th-magnitude 81 Aquarii for observers in the Gulf States. ■

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This month's hot new products . . .

Celestron 11" scopes starting at only \$1699.

Celestron's new 11" Schmidt-Cassegrains make state-of-the-art big aperture telescopes affordable for almost everyone. For about the cost of a competitive 8" fork-mount go-to scope, you can have a Celestron 11" that has almost twice the light-gathering of the 8" for seeing fainter deep space objects and almost 40% more resolving power to reveal planetary detail!

These 11" **Celestron Advanced Series** telescopes put multicoated optics on easy-to-use equatorial and computerized go-to mounts. Scopes available from our stock include:

the C11S on an equatorial mount **\$1699⁹⁵**
the C11S with XLT coatings **1979⁹⁵**
the C11S-GT go-to equatorial **1999⁹⁵**
the C11S-GT with XLT coatings **2279⁹⁵**

Each 11" Celestron Advanced Series C11S has a heavy duty adjustable height tripod with sturdy 2" diameter tubular steel legs, slow motion controls, setting circles, 1.25" 40mm Plössl eyepiece, a big 9 x 50mm finderscope, and more. For extra-bright images, Starbright multicoated optics are standard equipment, not

an optional extra, as with other scopes. And for those who want the ultimate in image brightness, optional state-of-the-art Starbright XLT multi-coatings can give images that are up to 16% brighter than even the legendary Starbright coatings. An optional and inexpensive dual-axis drive and drive corrector combination is available to motorize each scope.

The computerized C11S-GT (go-to) versions have all of the standard features listed above, plus dual motor drives and a built-in computer that takes the guesswork out of finding your way around the skies. It can automatically find and track over 45,000 stars and objects for you.

The scopes are easy to transport and set up (the heaviest component weighs only 29 lbs.) And, best of all, they're affordable. Big optics no longer cost a fortune, thanks to Celestron.



Sell your used telescopes and accessories quickly for free by using the no-charge classified ads at www.astrofieds.com

Only \$995 for a 5" GPS-ready Celestron SCT.

The **Celestron NexStar 5i** is the *only* 5" telescope that has automatic GPS satellite alignment available as an option. The NexStar 5i has a computer hand control with a 45,000+ star and object database, adjustable height tripod, red dot finder, eyepiece – everything you need to start observing immediately!

Multicoated optics are *standard equipment* with the Celestron NexStar 5i, not an option as with other scopes. NASA uses Celestron 5" multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium image quality?

And if you want something a little larger, the **Celestron NexStar 8i** has all the features of the NexStar 5i, but with an 8" optical tube for two and a half times the light-gathering, at a cost of only \$1379.



the NexStar 5i is shown with optional photography accessories

and a new and improved website at www.astronomics.com!

We've added more products and features to our website. There are calculators – for CCD

cameras, eyepieces, Barlows, camera adapters, and more. You can do side-by-side product

comparisons. Looking for a particular product? We tell you if you can save money on a used

one. And that's just a taste of the expanded Astronomics website features in store for you.

\$399⁹⁵ for a 130mm Maksutov. \$209⁹⁵ for a 90mm.

The new **Celestron C130M Maksutov** has a dovetail that will let you install it on a \$399 Celestron CG5A German equatorial mount (or on a \$749 Advanced Series go-to mount), as well as on a standard photo tripod. You get the best of all worlds – astronomical viewing as well as terrestrial. The C130M has a big 10 x 50mm finder, dust caps, 45° image-erecting diagonal for nature studies (as well as a built-in 90° star

diagonal for sky viewing), 32mm 1.25" Plössl eyepiece (64x), a soft case, and more.

The Celestron C130M is an easy (and very cost-effective) way to get into the world of high power Maksutov optics.

And there's a **C90M** waterproof 90mm version of the C130M available for only \$209.95!



Hot scopes and accessories from William Optics.

How much would you pay for a 97% reflectivity 1/10th wave accuracy 2" enhanced aluminum mirror diagonal with 1.25" eyepiece adapter? Some competitors charge up to \$250 for that combination. But the **William Optics 2" diagonal** shown above (our part #W2) is only \$130!

A 2" 99% reflectivity 1/10th wave accuracy dielectric mirror diagonal for Schmidt-Cassegrains, with a 1.25" eyepiece adapter, costs a total of \$360 from a competitor. But the **William Optics dielectric diagonal** to the right (our #W2DSC) is only \$230!

The 2" rotatable Schmidt-Cassegrain zero image shift Crayford-style manual focuser with

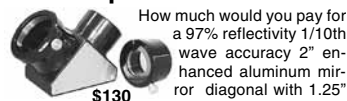


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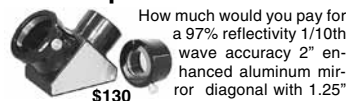


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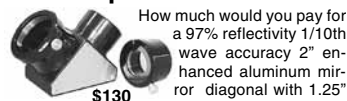


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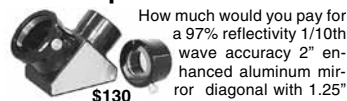


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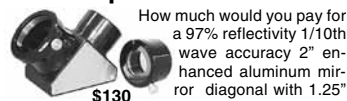


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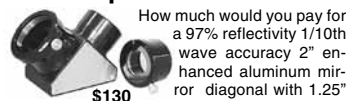


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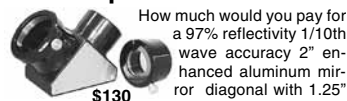


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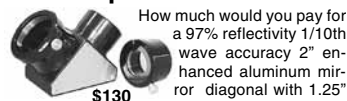


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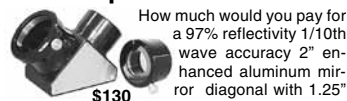


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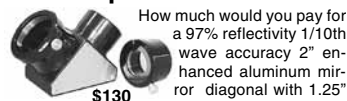


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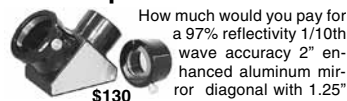


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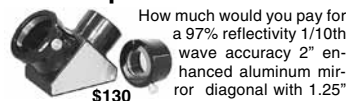


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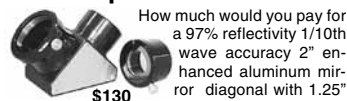


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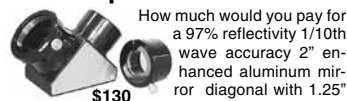


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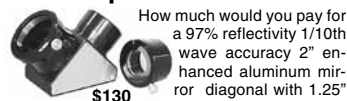


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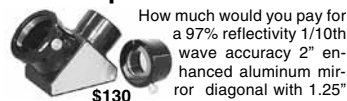


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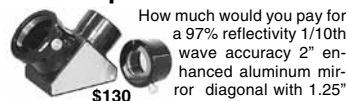


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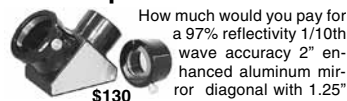


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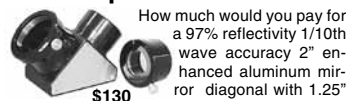


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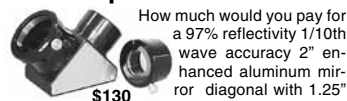


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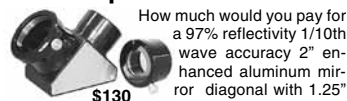


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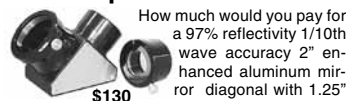


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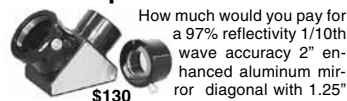


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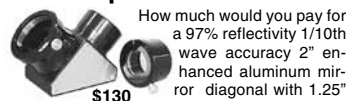


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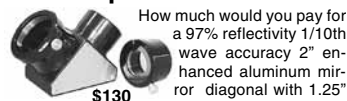


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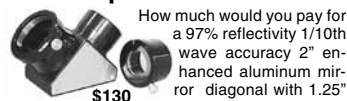


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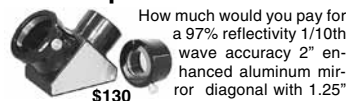


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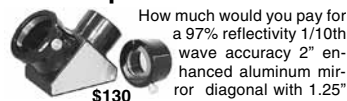


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ASK ASTRO

Observing Wolf-Rayet stars, career paths, and giant-planet winds

OBSERVING WOLF-RAYET STARS

I'm fascinated by Wolf-Rayet stars and want to know more about them. Are some of them observable with a small (4-inch) telescope? — PETE STINGLEY, REEDSPORT, OREGON

Wolf-Rayets (WR) are hot, young, massive, luminous stars with vigorous stellar winds. They are also rare. Astronomers have identified only 226 in our galaxy and estimate the Milky Way may hold as few as 1,000. Despite these low numbers, WR stars play an important role in the galaxy's physical and chemical evolution.

WR stars have typical masses around 20 times greater than the Sun's and probably represent the last stage in the evolution of

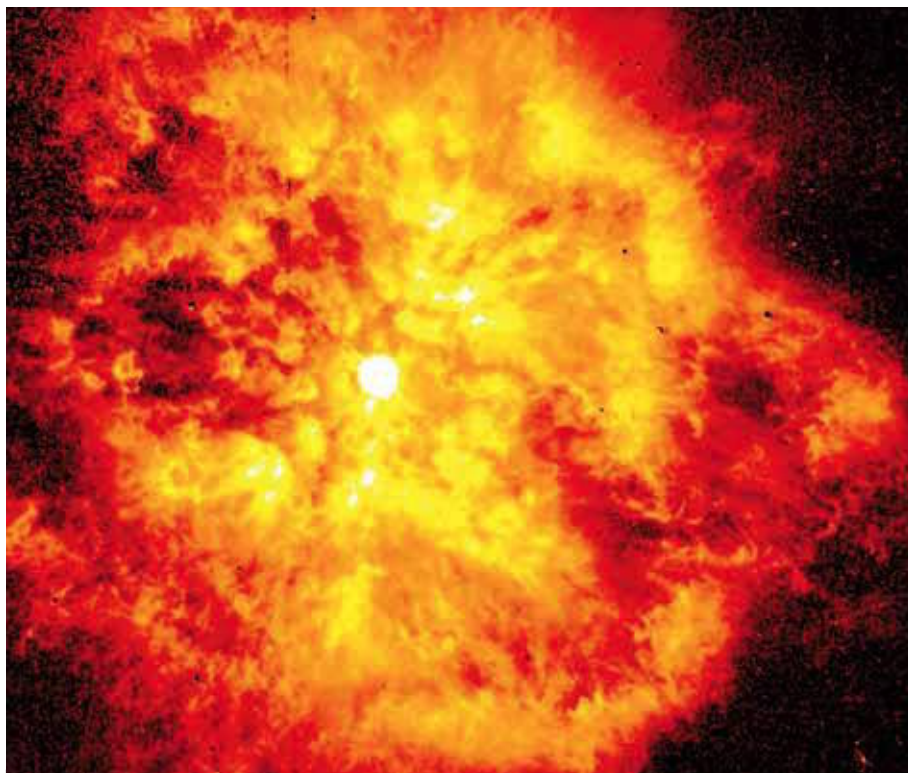
massive O-type stars. WR stars likely end their lives as either type Ib or Ic supernovae, which also are associated with gamma-ray bursts. Long before these stars explode, they leave their imprint on the interstellar medium. Their high surface temperatures (50,000 kelvins and up) and luminosities (100,000 suns and greater) drive stellar winds as fast as 1,500 miles (2,500 kilometers) per second. Such winds remove up to two-thirds of the star's origi-

nal mass and, throughout the lifetime of the WR phase, release kinetic energy comparable to the amount produced by the supernova explosion that follows. Some WR stars occur in binary star systems, so in these cases, transfer to a close stellar companion may help them lose mass, too.

The most distinguishing characteristic of a WR star is its spectrum. In 1867, this is what caught the eyes of French astronomers Charles Wolf and Georges Rayet, who first described these peculiar stars while using a visual spectroscope at the Paris Observatory. Hydrogen is absent in nearly all WR spectra because stellar winds have stripped the stars of their hydrogen envelopes. What's left is essentially a bare stellar core, rich with helium, carbon, and other products of advanced nuclear burning. Because these elements also are being blown off by stellar winds, WR stars enrich the space around them with heavier elements.

Observers in the Southern Hemisphere and at low northern latitudes easily can see one WR star with the naked eye: Gamma² (γ²) Velorum. Part of a well-known multiple star system, Gamma² Velorum shines at magnitude 1.8 in the constellation Vela and lies about 840 light-years away. This star is really two: a WR star and its brighter type O companion. The two wheel about one another every 78.5 days. Separated only by about the distance between Earth and the Sun, the two cannot be resolved as individual stars in a telescope.

The brightest WR star visible to everyone in the Northern Hemisphere is 6.7-magnitude HD 190918, also known as SAO 69402 and numbered 133 in the catalog of known Milky Way WR stars. WR 133, which also has an O-type companion star, is associated with NGC 6871, a young open star cluster located near the center of the "cross" in Cygnus. — FRANCIS REDDY, ASSOCIATE EDITOR



WR STARS SHED their outer layers in a kind of slow-motion explosion. QR Sagittae, also known as WR 124, seems to be disintegrating in this Hubble Space Telescope view — an impression that isn't far from the truth. The star is shedding its outermost layers quickly to form the surrounding nebula, cataloged as M1–67. Both are located 15,000 light-years from Earth. NASA/STScI/Y. GROSIDIER (UNIV. MONTREAL)

CAREER PATHS

I am obsessed with astronomy and soon will enter college. What are the best areas of study for a career in astronomy? — RACHEL FAULKNER,

LEWISTON, IDAHO

Traditionally, the best areas of focus for potential astronomers are physics and mathematics or, if you go to a school with an undergraduate program in astronomy, astronomy and physics. Mathematics is indeed important, but less so than an understanding of the natural world imparted by studying physics. Think about all the stuff out there in the cosmos — planets, stars, gaseous nebulae, star clusters, binary stars, white dwarfs, pulsars, and black holes, to name just a few — physics provides the key to unraveling their mysteries, which often are described in the language of mathematics.

So if I were you, I would probably major in astronomy — if your chosen school has such an undergraduate program — and minor in physics. Otherwise, choose physics as your major and then minor in mathematics.

There are certain specialties within astronomy, such as exobiology, in which knowledge of chemistry (and biology) is invaluable. But most folks wait until graduate school before becoming this specialized. A broad background in astronomy and physics is very important for success these days. Be versatile. — BILL COOKE, MARSHALL SPACE FLIGHT CENTER

GIANT-PLANET WINDS

I recently read about the high wind speeds on Saturn and the other gas-giant planets. What is wind speed on a gas giant measured relative to?

— ORION CARRIER, VICTORIA, BRITISH COLUMBIA

The deep rotation of the gas giants serves as the yardstick for determining how fast their winds blow.

At the equator, Saturn rotates in 10 hours, 14 minutes. Planetary scientists



SATURN HAS THE FASTEST WINDS of the gas-giant planets. Recent Hubble Space Telescope observations indicate that equatorial winds now blow about 60-percent slower than they did when the Voyager spacecraft flew past the planet in 1980 and 1981. Scientists hope that data from the Cassini spacecraft, now in orbit around Saturn, will help them understand this puzzling slow-down. On May 21, 2004, Cassini captured this image of intriguing cloud structures from 13.7 million miles (22 million kilometers) away. NASA/JPL/SSI

determine this rotation period by looking at radio waves (mostly in the decimeter wavelength range) generated deep within Saturn's interior. As the planet rotates, the radio waves oscillate in a periodic fashion, and the pattern can be analyzed to determine how fast the planet's equator rotates. Saturn's giant magnetosphere also makes one complete sweep around the planet in the same period. This structure is created by Saturn's magnetic field, generated by a layer of electrically conductive liquid hydrogen deep inside the planet.

Atmospheric winds form as counter-flowing east-west streams. Planetary scientists determine wind speeds in all the giant-planet atmospheres by tracking visible cloud features and measuring their speeds relative to the planet's internal rota-

tion rate as seen in radio waves. At its equator, Saturn has wind speeds about 1,100 miles (1,800 kilometers) per hour faster than the internal rotational period. Saturn's internal heat, welling up from below, drives this faster motion. Recent observations with the Hubble Space Telescope indicate Saturn's fastest equatorial winds have slowed to about 690 miles (1,100 km) per hour.

Jupiter, which spins once in about 10 hours, has much slower winds than Saturn — typically about 335 miles (540 km) per hour faster than the internal rotation rate. The situation is more complex for Uranus and Neptune, which respectively have magnetic fields offset by 60° and 47° from their rotational axes. — RICHARD CROWE, UNIVERSITY OF HAWAII AT HILO



AMATEUR ASTRONOMY

Setting up for backyard observing just got a lot easier. /// RUBEN KIER

Build an astro-shed

Like many serious amateur astronomers, I dreamed of having a full-time observatory that would minimize setup time required on each clear night. This desire intensified when I began CCD imaging, which demands precise polar alignment, wind protection, and electrical power.

A roll-off roof observatory was not possible because my small, suburban backyard is heavily wooded on one side and largely occupied with leaching fields for a septic system on the other side. Because of my wife's aesthetic tastes, an observatory dome was not a consideration either.

My daughter Melanie — a fellow astronomy enthusiast — suggested a compromise based on the Sloan Digital Sky Survey site in New Mexico. The Sloan telescope is not in a typical observatory. Rather, a close-fitting shelter slides back to expose the telescope. So instead of building an observatory at our home, we began to consider a small shed that we could roll back for imaging.

Surfing for solutions

Doing some research, I found astronomers have a variety of telescope sheds. My friend,

Chuck Brown, built a small wooden “out-house” for an 8-inch Schmidt-Cassegrain telescope. John Gillies, an astronomer in southern Ontario, uses a prefabricated vinyl shed to enclose a 12-inch Meade Schmidt-Cassegrain scope on a fork mount. At the Star Hill Inn in New Mexico, owner Phil Mahon uses five wooden sheds with metal roofs for a variety of telescopes ranging from a 7-inch refractor to a 22-inch Dobsonian. I adopted Gillies's design combined with a dedicated observing deck built around a pier.

Building the astro-shed

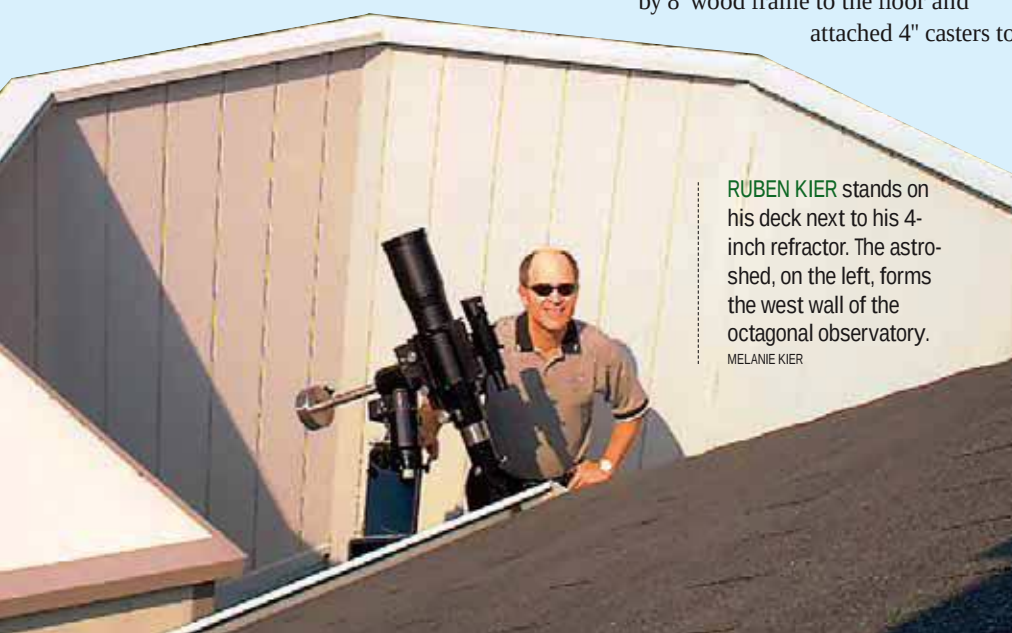
I purchased a premanufactured shed, the Royal YardMate Y436, from Lowe's home improvement store. Although I am not handy with tools, I assembled it in 4 hours. It has a sturdy fiberglass floor. I added a 2' by 8' wood frame to the floor and attached 4" casters to

the wooden frame. The telescope height on the pier and the need for the open doorway of the rolling shed to clear the top of the scope determined the height of the frame. For others adopting this design, different combinations of pier and telescope will determine the height of the wooden base. The total cost for the shed, base materials, and casters was less than \$400.

My astro-shed measures 6 feet high, 4 feet wide, and 3 feet deep, with a tall, wide doorway. The size is generous for either my 4-inch refractor or my 8-inch Schmidt-Cassegrain on a German equatorial mount. This mount is sturdy enough that it could accommodate a 12-inch Schmidt-Cassegrain on a fork mount or even a 15-inch Newtonian reflector. The shed's double-wall vinyl construction protects and insulates the contents from the elements without concern from rust or rot and does not need painting. It has proven watertight through torrential downpours, and its light color and side vents keep optics from baking on 90° F and warmer days. For wooden sheds, Mahon recommends fiberboard insulation. His sheds have an open floor for ventilation; frequent use keeps animals and insects from finding a home. For more occasional use in a backyard, the solid floor like mine is necessary.

To fit the shed around my pier, I used a portable jigsaw to cut a horseshoe-shaped section from the base of the shed. I trimmed the floor piece I cut out to fit around the pier to keep out pests. I attached metal bars over this cutout piece, both to act as a handle and to keep the cutout from falling through the floor gap.

Ruben Kier is a radiologist practicing in New England who has served as associate editor of the journal Radiology. Melanie Kier is a 10th-grade student who took first prize in the junior division of Astronomy's 25th Anniversary Photo Contest in 1999.



RUBEN KIER stands on his deck next to his 4-inch refractor. The astro-shed, on the left, forms the west wall of the octagonal observatory.

MELANIE KIER



MELANIE KIER stands next to the astro-shed with her 8-inch Schmidt-Cassegrain telescope. Within the shed, the cut-out from the horseshoe opening is propped on the back of the shed floor. RUBEN KIER

Observers use a variety of piers with roll-away sheds, including both concrete piers and steel piers anchored in concrete. If you place a pier through a wooden deck, remember to isolate the deck from the pier: Leave a narrow space around the pier to avoid deck vibrations. Construct the pier before building the astro-shed to make sure the wooden base is the correct height and the floor's cutout is the proper size.

Although the astro-shed design works best around a pier, it also can be adapted for Dobsonian-mounted telescopes. If a Dob is used through a wooden deck, an isolated, square concrete slab can eliminate transmission of vibrations. Roll-away sheds are less useful for standard tripods because just about all tripod legs spread too wide for the shed.

The astro-shed design can be used on any pre-existing deck or patio. Because I was remodeling my backyard deck, I decided to construct a customized section for my astro-shed.

A PREFABRICATED VINYL SHED encloses the 12-inch Schmidt-Cassegrain telescope owned by John Gillies of Ontario, Canada. JOHN GILLIES

I designed the deck as an octagon open at the top with six walls enclosing the north, east, and south sides. The shed rolls to shelter the west side of my observing deck and with the door open, completes the octagonal shape of the observing platform. The walls are 6'8" high to provide shielding from neighbors' lights and protection from wind.

For economy, the wall sections utilize standard 4-foot-wide panels secured with 4x4 pressure-treated posts that sit on concrete footings separate from the pier. The

When I peered through a window, watching my father diligently working on his CCD imaging in the backyard, I thought he had gone crazy. He spent countless hours setting up his equipment and hooking up all the essentials, only to blow a fuse when the clouds rolled in before he could start imaging. Well, my dad is still crazy, but the house remains much calmer when the clouds return. He just rolls his astro-shed back over his setup, determined to try again the next night.

The astro-shed is so simple to use that now I find the time to take my own images. Yes, even a teenager can enjoy CCD imaging when setup time is minimized. Between homework and social commitments, I can usually sandwich in imaging one or two objects each month. The February 2003 issue of *Astronomy*, which showed *Astronomy's* Top 10 deep-sky objects, inspired me to undertake the challenge. I decided to image these 10 objects during the coming year as a project of my own. You can follow my progress on my web site, www.star-teen.org. — Melanie Kier

inside diameter of the enclosed deck is 9'6", providing a cozy enclosure for as many as three observers. With the pier slightly off-center to the north, I can see to within 35° of the northern horizon, 30° of the eastern horizon, and 25° of the southern. I can't see much closer to the horizon anyway because of trees and light pollution. A 4-inch space at the bottom of the walls allows for snow removal, permitting year-round use of the astro-shed.

Rolling out my conclusion

My astro-shed has provided me the efficiency of a dedicated observatory without the real-estate demands of a roll-off roof observatory. I can begin or shut down an observing session in less than 10 minutes and can keep a sophisticated CCD setup unattended for days without exposing my equipment to the elements. For a fraction of the cost of an observatory, a prefabricated garden shed can be assembled and modified in a single weekend to provide an efficient shelter for a backyard telescope. ■





MOON OBSERVER'S NOTEBOOK

The northeastern shore of Mare Imbrium contains some of the Moon's most interesting — and challenging — scenes for observers. /// BY ROBERT BURNHAM

Rambling in the lunar Alps

An evening or two past First Quarter Moon — or the same time before Last Quarter — sunlight falls invitingly across the rugged terrain that flanks the northeastern and northern edges of Mare Imbrium. These highlands are the Montes Alpes, the lunar Alps. Unlike Earth's tectonically created mountains, however, the Alps

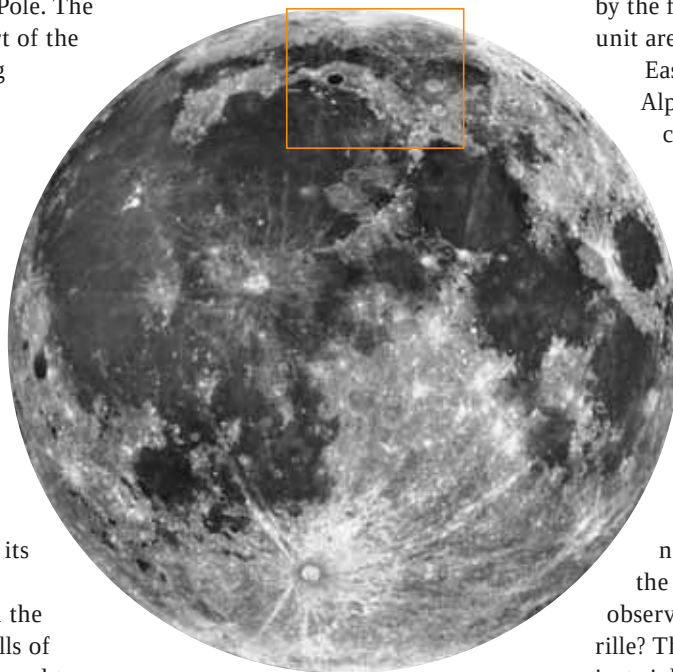
form part of a gigantic crater rim: the boundary of the Imbrium basin, created when an asteroid struck the Moon 3.85 billion years ago. The Apennines that lie to the southeast of Imbrium also belong to its rim, as do the Montes Carpatius on Imbrium's southern side.

North of the Alps, a slender dark strip called Mare Frigoris divides this stretch of lunar mountains from heavily cratered highlands running to the North Pole. The lava of Frigoris fills a trough, part of the multi-ring structure surrounding Imbrium and most large impact basins. Mare Frigoris continues eastward from the region in the photo, where it fills a similar trough outside the Serenitatis impact basin, Imbrium's slightly older (3.87 billion years) neighbor.

The highest peak in the Alps is Mont Blanc, which stands 11,800 feet above Mare Imbrium. Note that this mountain is called "Mont" not "Mons" Blanc, as you might expect. This peak was named for its earthly counterpart. The "front range" of the Alps is steeper than the backslope, just as the interior walls of craters show steeper slopes compared to their exterior ejecta blankets. Poking up through the mare surface are several short mountain ranges and individual peaks; for example, the Montes Piton, Pico,

and Teneriffe, all reaching some 6,500 feet. These are remnants of a structural ring within the basin, which has been all but obliterated.

The most eye-catching feature in the region is Plato, with its dark floor that often mesmerizes observers. At 63 miles across, Plato isn't large by lunar standards, but its contrast with the highlands



EXPLORE THE LUNAR ALPS with the help of this locator map. This image is oriented as you'd see the Moon in the sky, with north at the top. LUNAR AND PLANETARY LABORATORY

/// BEST DATES TO OBSERVE

Lunar sunrise and sunset are the best times to view the Moon because shadow detail is greatest then. The best dates to observe the lunar Alps for the next three months are listed below.

Lunar sunrise

Nov. 19–21, Dec. 19–21, Jan. 18–20

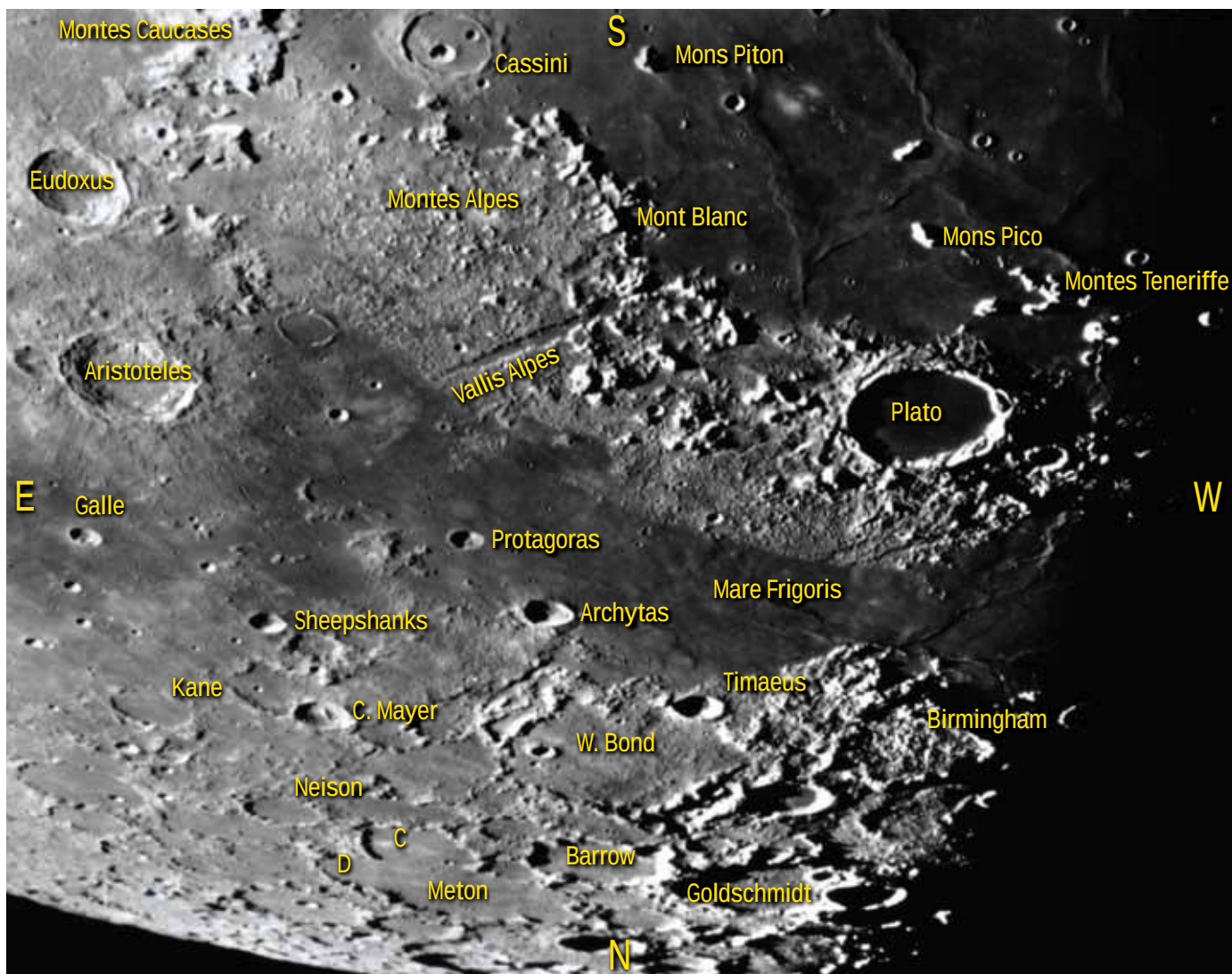
Lunar sunset

Nov. 1–3, Dec. 2–4, Dec. 31–Jan. 3

makes it just visible to sharp naked eyes on Earth. The crater formed after the basin impact. However, its lava filling is younger than Mare Imbrium, indicated by the fact that it has fewer craters per unit area than the mare.

East from Plato lies the famous Alpine Valley (Vallis Alpes), which carves a 120-mile path in the mountains from Imbrium to Frigoris. (It doesn't quite reach Frigoris, however, and the opening to Imbrium is pinched.) Lunar geologists see the valley as a graben, a collapsed block of terrain between two faults. The faults were born in the Imbrium basin impact and underwent tension as the lunar mantle domed upward slightly under the newly made basin. Snaking down the center of the valley is a notorious observing challenge: Can you spot the rille? The lighting and seeing have to be just right and a telescope with at least a 6-inch aperture is needed. Good luck!

Like Plato, Cassini postdates the Imbrium basin and has seen modification. This 35-mile-wide crater contains



THE LUNAR ALPS lie on the northeastern edge of Mare Imbrium. South is at the top, mimicking the view through most telescopes. LICK OBSERVATORY

two smaller impact craters dropped into its lava filling, which stands higher than the mare outside. Also, the lava that filled the Imbrium basin has truncated Cassini's ejecta blanket. Thus the crater's original morphology has been lost.

What Cassini probably looked like when fresh can be seen in a glance at Eudoxus, a 42-mile-wide crater northeast of Cassini. Often paired with the wider (55 miles) Aristoteles nearby, Eudoxus shows the classic form of a medium-size impact crater. The interior shows slumped wall terraces, multiple central peaks, and pools of impact melt on the floor. On a night with good seeing, shift your telescope from Cassini to Eudoxus and compare the two.

Robert Burnham, a senior editor of *Astronomy*, is the author of the recent *Exploring the Starry Sky* (Cambridge University Press).

Aristoteles formed mostly on the mare surface, so its ejecta pattern shows up more clearly than Eudoxus's. Again, with good seeing, a low Sun angle, and 150x, look for the strings of debris running radially away from it.

To the north of Mare Frigoris lie many large, shallow impact craters, often heavily modified and very old. The widest is W. Bond (98 miles), whose western side shows a startling degree of angularity. This appears due to sculpting by random smaller impacts just outside the crater's original wall.

Another large, flat crater is Meton (76 miles), which is actually several merged craters. Meton proper forms the northern part, while Meton C and D make large "bays" on the eastern and southern sides. The entire Meton structure predates Mare Frigoris because the mare lavas have flooded the crater complex. Similar

flooding has leveled the interior of Barrow (57 miles) and at least partly flattened that of Goldschmidt (75 miles).

Caught at sunrise, Birmingham (57 miles) just emerges into daylight. Birmingham has a rugged floor — obviously unflooded — that stands forth with great clarity under this lighting.

Throughout this region, the larger craters show signs they have been battered and resurfaced. Many also appear overlain with ejecta from more recent basin-making impacts, most notably Imbrium. Viewing these craters is tricky because of the oblique angle. Geological details fade and merge into the shadows.

Yet for all its difficulties, observing the lunar landscape from such an angle lets us imagine ourselves in orbit over the Moon, perhaps readying a lander for descent to the surface. It's eyepiece astronautics at its best. ■



ASTRONOMICAL HISTORY

The era of the personal telescope began about 50 years ago, when a mass market arose after World War II. Telescope progress has been astounding. /// BY MICHAEL E. BAKICH

The backyard telescope

“Should I bring the 6-inch apo, the 12-inch SCT, or the 24-inch Dob?” ◀ This question was posed to me by a friend whom I’d asked to go observing one Saturday night a few years ago. I thought, “Wow, it hasn’t been that many years since none of these scopes would have been available to us.” ◀ The development of backyard

telescopes in general is fascinating, and modern amateur telescopes comprise the largest part of that story — one filled with invention, innovation, and opportunity. But first a bit of history.

Once upon a time — before World War II — essentially all telescopes were amateur telescopes because there were no mass-market telescope manufacturers. There wasn’t even a mass market. Every instrument was largely one-of-a-kind, handcrafted, and priced accordingly.

During the 19th and early 20th centuries, a well-to-do individual typically would order a telescope from an instrument maker, such as Alvan Clark of Cambridge, Massachusetts, or John Brashear of Pittsburgh, Pennsylvania. This telescope then would be placed in a private observatory, where the owner — who was nearly always a “he” — pursued his astronomical field of interest: monitoring the brightness of variable stars, measuring double stars, looking for changes on the Moon, or simply poking around the sky to see the sights.

Telescopes varied in aperture, but usually fell into two categories: achromatic refractors in the 3- to 6-inch size and Newtonian reflectors with apertures running to 10 or 12 inches at most. Such instruments were very well made but cost several weeks’ wages for a worker.

Michael E. Bakich is an associate editor of *Astronomy*.

Because of the high prices in the early 20th century, making one’s own telescope began to attract a following. In 1921, an article in *Popular Astronomy* by Russell Porter of Springfield, Vermont, told how to make “The Poor Man’s Telescope.” His idea quickly caught on, and planetaria and astronomy clubs established workshops where astronomy buffs could meet regularly to grind mirrors and lenses for homebuilt telescopes. Regular articles in *Scientific American* gave the new hobby wider renown and encouraged the growth of the amateur telescope maker, or ATM. Porter’s own telescope-making club in Springfield established an annual meeting to share ideas and show off the members’ work. Called Stellafane, the meeting still continues and, held every August, it attracts ATMs from all over.

Telescopes in the space age

But not everyone interested in observing the sky had the tools or the talent to fabricate a telescope, a situation that didn’t improve until after World War II, when peacetime prosperity created more opportunities. By the 1950s, amateur astronomers began to purchase telescopes made by small manufacturers, some of whom had learned to work optics during the war. Newtonian reflectors were popular because they were easier to make than refractors and offered larger apertures for the dollar. ATMs also benefited from the times, making use of

the government surplus optical gear dumped on the postwar market.

At the end of the 1950s, four major manufacturers of amateur telescopes were in business, and several other companies were getting interested in selling telescopes. Criterion Manufacturing Company, founded in the 1940s, made Newtonian reflectors. In 1957, Criterion began selling the Dynascope, one of the most popular Newtonian reflectors ever made. The 6-inch f/8 model on a motor-driven equatorial mounting and priced at \$200 remained in production well into the 1980s.

Cave Optical Company, another famous maker of Newtonian reflectors, was founded in 1950. Cave introduced a telescope called the Astrola in 6-inch, 8-inch, and 10-inch models.

Unitron (the instrument division of United Trading Co.) made high-quality, long-focal-length achromatic refractors. Starting operation in 1951, Unitron offered a popular time-payment plan. Buyers put 10 percent down and used the telescope while paying off the balance over a year.

Questar Corporation produced a compact telescope that used a Maksutov-Cassegrain optical design, which combines a lens and a mirror. Questar completed its first instrument in 1953.

In the 1950s and 1960s, each of these companies produced thousands of high-quality telescopes that revealed celestial wonders to observers — and still do.

Other companies selling telescopes in the 1950s included Bausch & Lomb Optical, Coast Instruments, Edmund Scientific Co., J. W. Fecker, Goto Optical Manufacturing, and Nikon. Of all these companies, however, only Questar and Edmund Scientific are still selling telescopes today.



IT ALL BEGAN HERE. The amateur telescope-making movement originated in Springfield, Vermont, at Stellafane, the local club's meeting place. Innovative, homemade telescopes shown here and at similar meetings led to the birth of many commercial backyard telescopes. **JEFFREY HINES**

Developments in the 1950s did not revolve around reflectors solely. Refractor lenses acquired optical coatings, most notably with magnesium fluoride (MgF). These were developed to reduce light loss and internal reflections. In addition, a new type of glass, composed with calcium fluorite (CaF₂), was invented to reduce the chromatic aberration that even the best achromatic refractor lenses show under certain conditions. (The first fluorite telescope objective was offered in 1977 by Takahashi, Ltd. of Japan.)

The modern era

In 1970, Celestron Pacific (now Celestron LLC) of Torrance, California, introduced a telescope that took amateur astronomers by storm: the Celestron 8, or the C8 as skygazers soon were calling it. The introduction of this scope resembled that of the first IBM personal computers a decade later — it started a revolution. The orange-tubed Celestron 8 Schmidt-Cassegrain telescopes (SCTs) had many advantages — 8-inch aperture, light weight, portability (certainly better

than any 8-inch Newtonian reflector sold in 1970), and an f/10 optical system, which provided good magnification. A range of ready-to-use accessories made astrophotography simple and highly popular. The complete system included a wedge (for polar alignment and tracking) and a sturdy, folding tripod. Thousands of C8s were sold, despite a price of \$795 (not including the tripod).

The year after the debut of the Celestron 8, Celestron released a 5-inch f/1.65 Schmidt camera, which used single



CELESTRON opened a new era in backyard telescopes by offering sophisticated optics, relatively large apertures, and good portability in an affordable package. CELESTRON

pieces of cut 35mm film in a holder at the focus. Most amateurs who purchased the 5-inch Schmidt camera mounted it directly on their Celestron 8. This pairing made an impressive-looking setup, with the drive for the 8-inch scope being used to guide long exposures. Wide-field

images (mostly in color and usually of some region of the Milky Way) taken with Celestron's Schmidt camera were impressive and started many an astrophotographer's career.

In 1972, Celestron introduced the C5, a 5-inch equivalent of the Celestron 8. Due to its much lighter weight, the C5 (also with an orange tube) was popular, although not as much as the original 8-inch model. I remember being part of a group that observed with a C5 in the early 1970s. We all were struck by the excellence of the optics, the rapid setup time, and the relatively low price tag (\$625).

By the time the inaugural issue of *Astronomy* appeared in August 1973, Celestron was well established. On the back cover of our first issue, they advertised three models of Schmidt-Cassegrain telescopes — a 5-inch, an 8-inch, and a brand-new 14-inch. In addition, the image of the Rosette Nebula in the ad's background was taken through a Celestron 5-inch Schmidt camera.

In 1984, the Super C8 and Super C8+ were introduced. These models were the first significant upgrades to the basic Celestron 8, and they were quite well thought out. A 359-tooth worm gear drive with a single AC motor replaced the original two-motor, spur gear drive on both these systems. The worm gear tracked celestial objects more accurately than Celestron's first drive. The Super C8+, introduced at the same time as the

Super C8, added an 8x50 finder scope and a 1¼" mirror star diagonal, an improvement over the earlier prism diagonal. The mirror diagonal proved more efficient because it transmitted more light. In this same year, Celestron also upgraded its mounts. The Super C8 or Super C8+ could be mounted on Celestron's Super Polaris mount, into which an optional, small, polar-axis finder scope could be added for accurate alignment at setup.

The year 1984 also marked the change in the color palette for Celestron telescopes. Production of the signature orange tube stopped and the black tube made its debut. Celestron continues to use the black tube (with letters colored in the original orange) today.

Scopes for an expanding market

Today, the world leader in telescope sales is Meade Instruments of Irvine, California. But it wasn't always this way. Meade was founded in 1972 as a mail-order supplier of small refractors imported from Japan. Within a year, Meade was a supplier of eyepieces and parts for amateur telescope makers.

In 1977, 5 years after getting started, Meade was finally in position to offer its own line of manufactured telescopes. The company started with a pair of Newtonian reflectors. Model 628 (a 6-inch f/8) and Model 826 (an 8-inch f/6) were so popular that within a year, Meade was faced with a 6-month

1920s

1940s

1950s

'21 *Popular Astronomy* writer Russell Porter tells how to make "The Poor Man's Telescope."

'40 Criterion Manufacturing Company is founded.

'50 Amateur telescope makers benefit from postwar surplus optics.

Refractor lenses get optical coatings to reduce light loss and internal reflections.

Cave Optical Company introduces the Astrola, a Newtonian reflector in 6- to 10-inch models.

'51 Unitron starts operation and offers a popular payment plan for its achromatic refractors.

'53 Questar Corporation introduces a compact telescope that combines a lens and a mirror.

'57 Criterion offers the Dynascope, a 6-inch, equatorially mounted Newtonian reflector.

backlog, despite its advertised promise of 6- to 8-week delivery. In response, Meade executives sent personal letters to every customer who had ordered one of its scopes, offering a full and immediate refund if the wait time was unacceptable. Few accepted the offer, and Meade, by adding personnel and shifts, was able to ship all orders within 3 months.

Meade staked a big claim in the field with a full-color, two-page, inside-cover advertisement in the October 1980 *Astronomy*. But the ad wasn't the story, the product was. The ad marked the introduction of a brand-new line of Schmidt-Cassegrain telescopes — the System 2000. Meade engineers had begun designing this series in 1978, but the time and resources involved were such that it took nearly 3 years before the telescopes and related equipment were ready for the market.

The main telescope in the System 2000 line was Model 2080, with 8 inches of aperture. Among its features was the inclusion of a worm-gear drive for precision tracking, low periodic error, and zero backlash. The Meade 2080 was the first 8-inch Schmidt-Cassegrain telescope to contain such a drive. And the base price for the optical tube assembly and fork mount? \$785. (You had to add \$50 for an equatorial wedge plus another \$140 for a field tripod.)

Meade's System 2000 line also contained a 4-inch Schmidt-Cassegrain Photo-Guide telescope and a 4-inch

f/2.64 Schmidt camera. Each of these attached easily to the 8-inch Schmidt-Cassegrains. Meade also had a line of accessories and eyepieces to complement the new telescopes. Six years from the introduction of its Schmidt-Cassegrain telescope line, Meade rose to the top of the telescope hierarchy, becoming the world's leading telescope manufacturer.

Work at Meade didn't stop after its Schmidt-Cassegrain line was introduced. In fact, the engineers at Meade have been responsible for some notable advances in telescope design and accessories. Among them are integrated electronic drive systems for Schmidt-Cassegrains (in 1984), the first permanently programmed periodic-error-correction software (called the Smart Drive) in 1990, and the first fully computerized observatory-class Schmidt-Cassegrain telescope (the Meade 16-inch LX200) in 1994. At the same time, the company offered the AutoStar computer controller — the world's first computerized go-to system for commercial application. Meade was also the first to offer, in 2002, ultra-high transmission coatings for commercial Schmidt-Cassegrain telescopes, called the UHTC group.

In whatever countries Meade telescopes are marketed today, they outsell all other telescope brands combined. The Meade lineup of telescopes, binoculars, eyepieces, and accessories is large and getting bigger. With the growth, however,

comes a commitment to quality that has not wavered for 32 years.

Direct to you

In 1975, Orion Telescopes and Binoculars was established. The company distributes its telescopes through some dealers in the United States and internationally, and it has two retail stores in California. Most customers, however, order directly from Orion, which is



MEADE has the widest product range of any manufacturer. It offers telescopes of all kinds in different sizes with mountings that range from simple to highly sophisticated. MEADE

1960s

1970s

'67 John Dobson creates a simple altitude-azimuth mounting perfect for large Newtonian scopes. Thus is born the Dobsonian telescope.

'70 Celestron Pacific introduces the popular Celestron 8, soon known as the C8.

'71 Celestron releases a 5-inch f/1.65 Schmidt camera that many amateurs mount on the C8.

'72 Meade is founded as a mail-order supplier of small refractors imported from Japan.

'72 Celestron introduces the C5, a 5-inch version of the C8. It was popular due to its light weight and small size.

'73 Celestron offers a 14-inch Schmidt-Cassegrain telescope.

'75 Orion Telescopes and Binoculars is established.

'77 Edmund Scientific introduces the popular Astroscan—a 4¼-inch Newtonian reflector.

Meade offers a pair of reflectors so popular that orders are backlogged for months.

based in Santa Cruz, California. Orion began small, but its now extensive product line combines telescopes and accessories from a variety of manufacturers. Orion is the largest direct-to-consumer brand of telescopes and astronomy-related equipment in North America.

From the 1940s to the 1970s, Edmund Scientific, then located in Barrington, New Jersey, sold surplus motors and optical components, including a variety of small lenses and first-surface flat mirrors that were used by

ATMs. In 1977, Edmund



ORION adopts the bazaar approach — its telescope line blends products and accessories from many manufacturers.

ASTRONOMY: MAGGIE MCKEE

introduced the Astroscan — a 4¼-inch Newtonian reflector with a wide field of view. Because of its adjustment-free operation, small size, low cost, and fire-engine-red color, Edmund sold thousands of Astroscans. It was nearly impossible to go to a star party or observing session in the 1980s where somebody didn't have an Astroscan.

At first glance, the Astroscan (still Edmund's best-seller) looks like a fat-bottom Schmidt-Cassegrain telescope. The front glass is not a correcting lens, however. It's simply a flat window with an anti-reflection coating designed to keep dust out of the optics.

Because it is a great gift, an Astroscan has been the first telescope in the lives of many amateur astronomers. With its low power and wide field, the Astroscan provides great views of star clusters and the Milky Way, enticing beginning observers into purchasing telescopes that show more.

Return of the lens

After the introduction of the Schmidt-Cassegrain telescope, other types of telescopes continued to be produced, although a lot fewer were sold than in the 1960s. Just as with automobiles or music, no matter how many changes are made, some devotees remain loyal to a particular type of telescope. Thus, neither the refractor or the Newtonian reflector completely disappeared. Of



EDMUND SCIENTIFIC began by selling war-surplus optics. Its bright red Astroscan catches much attention. **STU EKSTRAND**

these, the first telescope design to be “reborn” was the refractor.

The first refractor lens to be labeled “color-free” was a triple-lens system created by Roland Christen and marketed by his company, Astro-Physics, Inc., in 1981. Astro-Physics, based in Rockford, Illinois, sold only two lenses at that time, a 6-inch (150mm) and an 8-inch (200mm). Both lenses were f/11 magnesium-fluoride-coated, oil-spaced triplets. This was the beginning of the new age of apochromatic (“without color”) refractors, usually dubbed “apos” by amateurs. Today's apochromatic objectives have two to four lens elements.

1980s

'80 Meade introduces the System 2000 line of improved Schmidt-Cassegrains.

Odyssey 1, the first large scope on a Dob mount, is introduced by Coulter Optical.

'81 Roland Christen of Astro-Physics creates the first refractor lens to be “color-free.”

'84 Meade releases integrated electronic drive systems for its Schmidt-Cassegrains.

1990s

'90 Astro-Physics releases synthetic fluorite ED glass, which eliminates color fringes.

Meade offers the Smart Drive, the first permanently programmed correction software.

'94 Autostar, the first computerized go-to system for commercial scopes, is introduced by Meade.

2000s

'02 Meade is the first to offer ultra-high transmission coatings for commercial SCTs.

'04 Go-to scopes make finding celestial objects easier and allow more observing time.

The integration of personal computers with scope drives and CCDs begins.

In 1990, Astro-Physics introduced a line of refractor lenses that incorporated synthetic fluoride ED (extra-low dispersion) glass in various optical designs. This optical material has all but eliminated color fringes around bright objects viewed through fast (low focal-ratio) refractors. If you're one of the many amateur astronomers today who desires an apochromatic refractor, you can thank Roland Christen.

Another company known for high-quality apochromatic refractors is Tele Vue of Chester, New York. While Tele Vue's founder, Al Nagler, is better known for creating two lines of wide-field eyepieces that deliver tack-sharp images — most advanced amateurs own at least one Tele Vue Nagler or Tele Vue Panoptic eyepiece — the company's refractors run second to none.

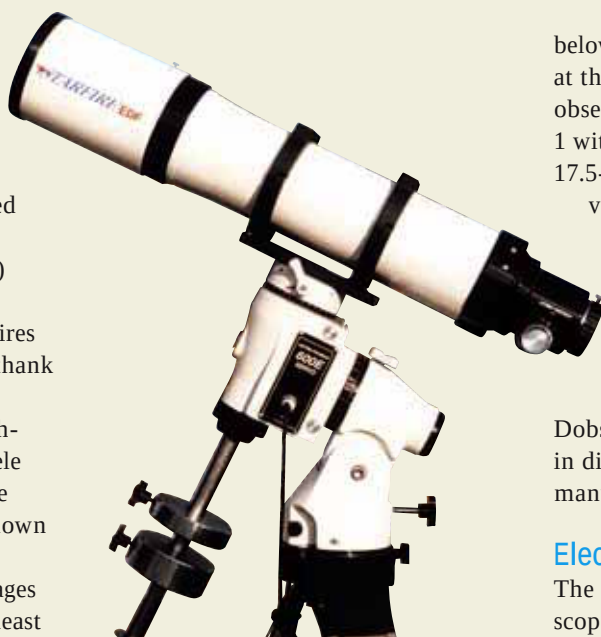
Tele Vue's apochromatic refractors begin with the highly portable 2.4-inch f/6 Tele Vue-60. The optical tube assembly of this scope weighs in at just over 3 pounds. On the other end of the scale is the 5-inch f/5.2 Tele Vue NP127. If you've never experienced views of celestial objects through a Tele Vue, ask for a look the next time you're at a star party.

Monsters on the field

After owning a telescope for a while, most amateur astronomers fall victim to a malady known as "aperture fever." Basically, it causes telescope owners to yearn for a larger scope — often a *much* larger telescope. Once the larger scope is bought, aperture fever vanishes — for a while — then it returns again. The condition can be alleviated only by the sad-denying realization that a yet-larger telescope will be more than the observer can



TELE VUE has a well-known line of top-notch eyepieces, but it also specializes in small, highly portable refractors. ASTRONOMY: MAGGIE McKEE



ASTRO-PHYSICS discovered there was a growing market for high-quality refractor telescopes with innovative optics riding on excellent mountings. ASTRONOMY: MAGGIE McKEE

handle; in essence, the scope would not be portable, an important consideration.

Early telescope manufacturers, for their part, could do only so much for portability. Equatorially mounted Newtonian reflectors with apertures more than 10 inches weigh a lot. But in 1967, a former Buddhist monk named John Dobson cobbled together a simple altitude-azimuth mounting that proved perfect for large Newtonian scopes — large meaning 12 inches and more. Dobson took his big Newtonians onto the sidewalks of San Francisco in a self-given mission to popularize astronomy.

His mounting, now known as the Dobsonian, or Dob, is simple to make and yields a telescope that's easily portable for its size.

The first manufacturer of large telescopes on Dobsonian mounts was Coulter Optical, then of Idyllwild, California. Its Odyssey 1 was a 13.1-inch f/4.5 telescope introduced in 1980. This model, whose \$500 price placed it far

below any comparably sized instrument at the time, was very popular with observers. Coulter followed the Odyssey 1 with the Odyssey 2, a truly massive 17.5-inch f/4.5 instrument that delivered views of faint deep-sky objects never before seen by most amateur astronomers. The excitement generated by the first really large Dobsonian-mounted scopes did not go unnoticed by other manufacturers, and today, Dobs containing mirrors up to 30 inches in diameter are available from several manufacturers.

Electronic skies

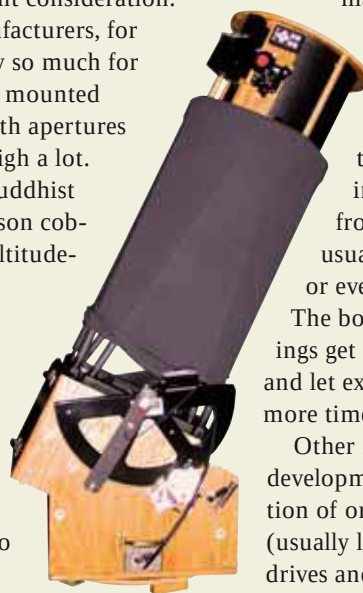
The current revolution in backyard telescopes lies in computerized control. All kinds of telescopes — refractors, reflectors, Schmidt-Cassegrains, even Dobs — are benefiting from developments in electronic control and pointing.

Go-to telescopes today have varying amounts of capability, but all of them make finding celestial objects easier. Essentially, you turn them on, locate a couple of known stars, and the telescope then takes over the job of finding objects. These are drawn from a built-in database that usually runs into the hundreds or even thousands of entries. The bottom line? Go-to mountings get beginners going sooner and let experienced observers spend more time observing.

Other recent computer-related developments include the integration of ordinary personal computers (usually laptops) with telescope drives and CCD electronic cameras.

Because the history of the amateur telescope continues to be written by manufacturers, dealers, and amateur astronomers, we're still at the beginning, not the end. Thanks to lots of innovative manufacturers and backyard tinkerers, even casual astronomers can own what was available only to the pros a few decades ago.

The past 50 years of amateur astronomy have taken us all on quite a ride. I can't wait to see what new worlds will open to us in the future. ■



STARMASTER is one of several manufacturers offering large reflectors carried on Dobsonian-style mountings. Such telescopes are highly portable. STARMASTER



EDUCATION

After nearly a decade, Project ASTRO continues to enhance astronomy education throughout America. /// BY JEREMY MCGOVERN

Classroom astronomy

An awe-inspiring subject to discuss, astronomy can be intimidating to teach. Kids and adults alike look up, marvel at the majestic beauty of those twinkling specks in the night sky and wonder, “What’s out there?” Then they look down, walk on, and ask themselves, “What time is *Friends* on?” Not until they find themselves in

the company of an astronomy-enthusiast do people really cut their cosmic curiosity loose. About 10 years ago, in an attempt to make astronomy more accessible, the Astronomical Society of the Pacific (ASP) engineered a program to bridge the gap between the astronomy-enthusiast and the astronomy-curious.

While attending summer workshops for teachers, Andrew Fraknoi, then executive director of the ASP, would come across elementary and middle-school teachers enthusiastic about educating students in astronomy but somewhat fearful of fielding students’ astronomy-related questions. Half-jokingly, many instructors would ask Fraknoi if the ASP could provide astronomers to help in the classroom. Fraknoi realized *all* the requests would be

impossible to fulfill, but he believed the ASP could enlist an army of astronomers to enter schools and assist teachers.

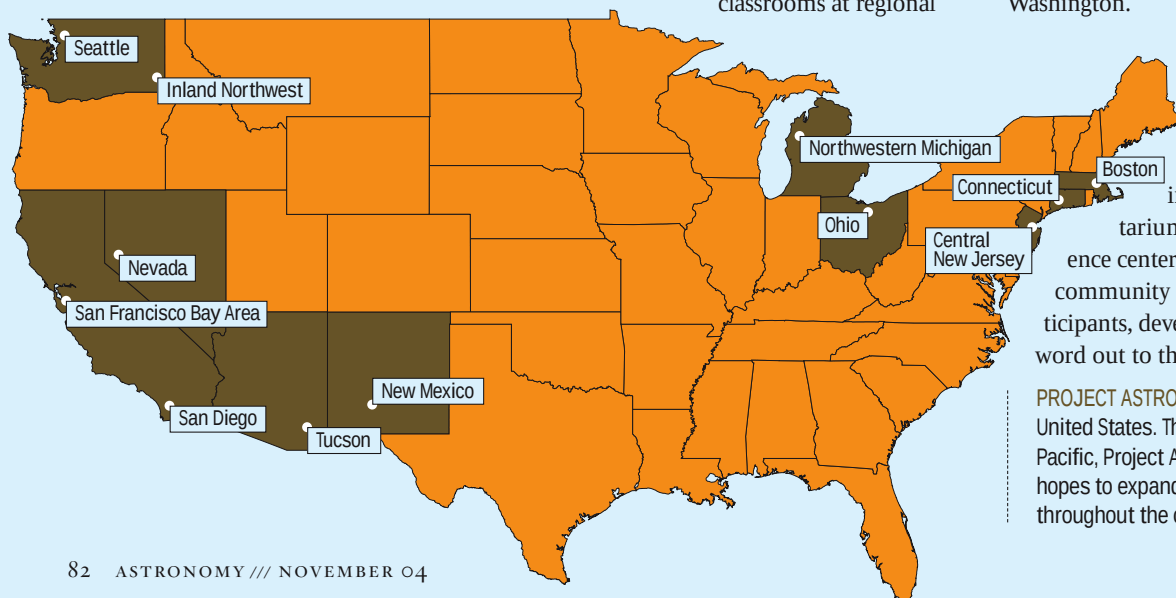
Born from these conversations with teachers was Project ASTRO. This innovative program joins amateur and professional astronomers with instructors throughout the United States to furnish 4th through 9th-grade students with a hands-on introduction to astronomy. Not only does this supplement the students’ education, but the collaboration also affords astronomers an opportunity to share their passion with others and give back to their community.

To launch Project ASTRO, the ASP applied for and obtained a grant from the National Science Foundation. With this funding, the program officially began in 1994, matching trained volunteers with classrooms at regional



A SAN FRANCISCO BAY AREA student models a spacesuit for her fellow Project ASTRO classmates. MIKE SMITHWICK

sites in Los Angeles and San Francisco. Now, Project ASTRO reaches out to more than 120,000 students through 12 sites in the United States. Project ASTRO national network sites are present in Arizona, California, Connecticut, Massachusetts, Michigan, New Jersey, New Mexico, Nevada, Ohio, and Washington.



Coming together

Each Project ASTRO regional site begins with an astronomy-related institution, such as a planetarium, an observatory, or a science center. The institution builds a community network that recruits participants, develops activities, and gets the word out to the public. Furnished with a

PROJECT ASTRO sites speckle this map of the United States. The Astronomical Society of the Pacific, Project ASTRO’s parent organization, hopes to expand the project to more areas throughout the country. PROJECT ASTRO



FIFTH-GRADE STUDENTS at Washington Elementary School in Edison, New Jersey, peer into the steam from their cosmic creation. Project ASTRO not only brings astronomy into the classroom, but it also helps children witness firsthand the dynamics of space-matter formation. SHARON RUSSELL-FOWLER

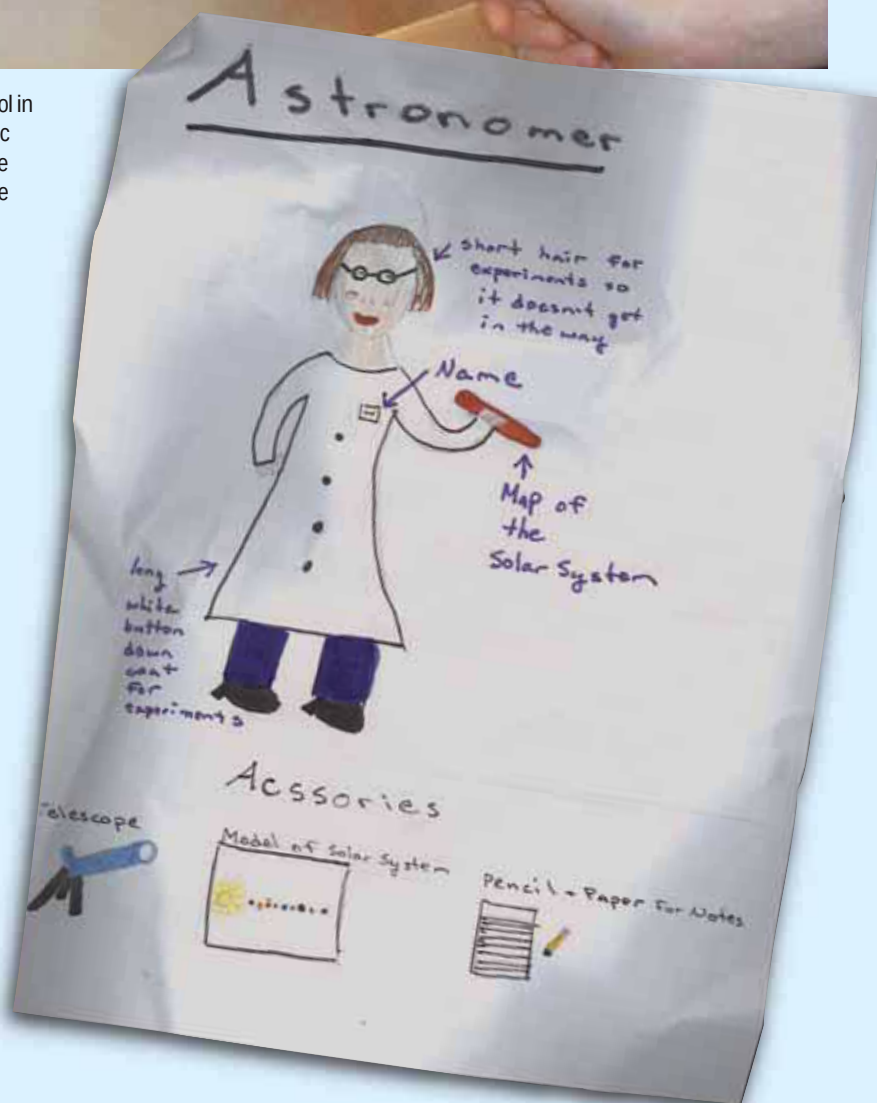
part-time staff, this business hub raises funds and acquires additional resources for their classrooms.

When the regional site is operational, the teacher-astronomer relationships are created. Matchmaking derives from sorting volunteers' applications and uniting them with a teacher based on criteria including location, grade level, and subject interest.

Some teachers may not have any astronomy background, while some volunteers may lack classroom instruction experience.

"The teacher may be a stronger communicator, whereas the astronomer has a better grasp of how a telescope works or how to observe constellations," says Dan Zevin, national coordinator for Project ASTRO.

CHILDRENS' DRAWINGS of astronomers usually portray astronomy's stigma of being carried out by white, bearded, bespectacled, graying men wearing lab coats. That's not the case, according to this drawing, "Astronomer," by a fifth-grader at High Bridge Elementary School, High Bridge, New Jersey.





STUDENTS BUILD THE SOLAR SYSTEM out of playdough during this project at an after-school program at Summerdale Elementary School in Barryessa, California. CATHY OLKIN

Into the classroom

In most cases, before an astronomer visits the classroom, the teacher asks the kids to draw a picture of an astronomer. The images show stereotypical views of astronomers, usually as a Caucasian man with a gray beard wearing a white lab coat. The classroom visit usually illustrates otherwise.

"Volunteers are optometrists, bankers, lawyers, people from diverse personal and professional backgrounds," explains Amie Gallagher, the coordinator of the New Jersey site with the Raritan Valley Community College Planetarium. "Besides, I want to show astronomy isn't necessarily a job, it is something people have fun doing outside of work. You don't need to make it a career."

Shattering these stereotypes is key not only to opening the students' minds but also to inspiring them. Connie Walker, coordinator of the Tucson site and National Optical Astronomy Observatories' Senior Science Education Specialist, comments, "By showing people [something counter to their] preconceived notions, you are showing that nothing is insurmountable — you can accomplish anything you set your mind to."

To prepare for classroom visits, Project ASTRO partnerships depend on *The Universe at Your Fingertips* and *More Universe at Your Fingertips*, resource guides filled with project ideas, lesson plans, and guidance from astronomy educators. To address an increasingly diverse classroom, the ASP came out with a Spanish version of the guide, *El Universo a Sus Pies* (see below).

"We want the instructor and the astronomer to rely on each other — they effectively teach by supporting each other."

Volunteers come from a wide range of backgrounds. Retired teachers, commercial pilots, doctors, and computer technicians who are backyard astronomers have joined Project ASTRO. Professors of astronomy and physics, graduate students, planetarium directors, and researchers have joined as well. The list includes many well-known

astronomers such as brown-dwarf pioneer Gibor Basri, planet finder Debra Fischer, X-ray expert Rick Harnden, and planetary astronomer Heidi Hammel.

The teacher and astronomer pairs come together in the summer for an annual workshop that they are required to complete before the classroom instruction. Led by "mentor educators" from the regional site, partners construct lesson plans and discuss program goals and teaching philosophies. National Project ASTRO also hosts an annual conference for regional site leaders to reflect and prepare for the upcoming school year and plan program direction.

Jeremy McGovern is editorial associate for *Astronomy*, where he spends the majority of his time working on *Astronomy.com*.

/// THE UNIVERSE AT YOUR FINGERTIPS

As the Hispanic population in the United States increases, educators need to meet the growing needs of students whose primary language is Spanish. With the lack of bilingual classes throughout most of the nation, these students many times are underserved. Not surprisingly, numerous Project ASTRO sites have encountered this problem and are taking steps to ensure that Spanish-speaking students have the same educational opportunities as their English-speaking classmates.

Providing learning materials in Spanish is a necessity. For the national endeavor, the Astronomical Society of the Pacific translated some of its guides into Spanish, including the *Night Sky Adventures* and *Universe at Your Fingertips*. Project ASTRO-Nevada obtained a Spanish version of David Levy's planisphere, "Guide to the Stars."

Of course, the primary objective of regional sites in battling language barriers is to recruit more bilingual volunteers. In many cases, finding people who are bilingual, interested in astronomy, and have the time to volunteer is difficult. But that difficulty does not stop Project ASTRO regional sites from continuing to reach out to Spanish-speaking students.

To increase the number of volunteers, Paul Guttman of Project ASTRO-Nevada would like to bring bilingual high-school students into the fold. These older students could serve as mentors to younger students and help build an interest in astronomy. His goal is to reward high-school volunteers with course credits at local junior colleges or qualification for National Merit Scholarships. Guttman believes this volunteer work could influence high-school students' career paths.

"Overall, my hope would be that this inspires the high-school students to think about later becoming teachers. There is a great need in underserved communities to have teachers who can bridge the language barrier and have a passion for the subject."

Compared to other sites, Project ASTRO-Tucson works with the most Spanish-speaking students. Lacking enough volunteers, this site employs Family ASTRO to target their Hispanic community (for more information on Family ASTRO, visit www.astronomy.com/toc). Connie Walker thinks while the success in reaching the child is important, reaching the parent is also vital.

"It is great when they see their child's face light up and take an interest in astronomy. By participating, they will take a greater interest in their child's education," Walker says.



FIFTH-GRADE GIRLS in the after-school program at Summerdale Elementary School hold up drawings they created of the constellations. Each student made a constellation from a pattern on a piece of paper and then made up a story to go with it. CATHY OLKIN

Activities range from hands-on, amusingly messy undertakings, like building a comet or crater, to advanced projects that involve previous lessons and incorporate mathematics, such as constructing a model of Saturn by calculating sizes from real data.

“My own experience in astronomy stemmed from an experience with a fourth grade teacher,” explains William Herbst from the Connecticut site and professor of astronomy at Wesleyan University in Middletown. “There is no doubt that we increase astronomy interest in many students and that we may have influenced the career choices and lives of some students.”

Challenges

Not all Project ASTRO regional sites triumph. The initial Los Angeles site founded in 1994 has since folded. A group in Utah is currently on hiatus, hoping to return to the national program soon. Success for any site is reliant on overcoming obstacles. While some site leaders express concerns about their rural locations or language barriers, a few similar problems seem to affect all sites.

A challenge for non-profit groups like Project ASTRO sites is funding. The ASP requires each site to be self-sufficient. Some sites turn to local businesses, educational foundations, and school boards for help. Using their ties to the amateur astronomy community, some sites have teamed with astronomy clubs to use star parties as fundraisers, such as Project ASTRO-New Mexico and the White Sands Star Party.

Finding and keeping volunteers can be daunting. Some people may never join because they feel they can't take the time from their schedules to visit a classroom four times a year. Many volunteers come from graduate school but leave the area to pursue careers in astronomy. Others have confessed to that all-too-common fear of performing in front of an audience.

“Some volunteers like the idea of working in the classroom but need to get over their first-time jitters,” says Philip Blanco of the San Diego site.

Blanco feels this universal apprehension causes the partnerships to stay grounded, especially if the teacher is too busy to prod the volunteer into action, or vice versa. After encouragement from the regional leaders and a few meetings under their belts, volunteers inevitably keep coming back.

“There is not a lack of passion and enthusiasm from the volunteers — some visit the classroom more than double our requirement of four times a year,” explains Zevin. “These are people who work full-time jobs yet take time out of their schedules not only to come into the classroom but to prepare activities for the students so they may share the subject they love.”

Some sites can't meet the demands of teachers waiting for help. Last year, however — for the first time in Project ASTRO's history — sites struggled to fill *teacher* spaces. Coordinators suspect that increased emphasis on standardized testing pressures teachers to abandon in-depth science instruction.

The most gratifying part of the experience for teachers and volunteers is entering a classroom where children have prepared many questions in anticipation of an astronomer's visit. Teacher Bridget McKay from Summerdale Elementary School in San Jose, California, shared her favorite experience, on volunteer Cathy Olkin's final visit to the classroom. Upon announcing that Olkin was moving to Colorado to work on the New Horizons mission to Pluto, she was greeted with a request typically reserved for celebrities. “One of the boys had sort of a delayed reaction to her comment and shouted ‘Cool! Can I have your autograph?’” recounts McKay. “Within seconds, all of the fifth graders were shouting ‘Can I have it, too?’”

Ten years and counting

As the first decade of its existence closes, what does the next decade have in store for Project ASTRO? Perhaps Andrew Fraknoi, the astronomer who fathered the program, sums it up best:

“The great thing about astronomy is that it is largely about community, and it possesses members who love any chance to share their excitement for astronomy. These are the people we are looking for, and our job is to get them into the classroom to share with those [who] need astronomy education the most.” ■



To learn more about Family ASTRO, visit www.astronomy.com/toc

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TELESCOPE REVIEW

From low-power, wide-field looks at the Milky Way to high-powered views of the planets, this small but mighty scope delivers. /// BY RAYMOND SHUBINSKI

The Tele Vue-60

My work for museums and planetaria takes me all over the world. I've observed the sky from the decks of ships, the Australian outback, the Andes Mountains in Peru, and many other places. My dilemma regarding telescope equipment always has been one of weight and portability. For many years, my solution has been a 4¼-inch

rich-field Newtonian reflector I made while in graduate school. The wide views of this f/4 scope continue to be a delight. And talk about easy to use — I'd just pick up its small case, hop in the car, and find a dark site to spend a few hours under the stars. I used that scope a lot, but I was frustrated at times because it didn't provide good high-power views. But what could I do? The choice was either high-quality, wide-field views or high-power views with a different scope. Not anymore.

The latest entry in Tele Vue's line delivers portability and a wide range of power. The new Tele Vue-60 is not a rich-field telescope but offers many of the advantages you would expect from a small, portable system.

Narrow and wide fields

The Tele Vue-60 has an amazing range of useful magnification. The three Tele Vue eyepieces I used magnified as low as 15x (24mm Panoptic) and as high as 144x (2.5mm Nagler). Mid-range (40x) was

provided by a 9mm Nagler. With the 24mm eyepiece at 15x, you can sit and browse through the Pleiades or view a gathering of planets. Eight Full Moons could fit across its field of view. Unlike my old rich-field with a view that crumbled with short-focal-length eyepieces, the Tele Vue-60 holds up well as you increase the power. Saturn's rings are seen clearly at 40x, Jupiter shows distinct banding, and the Galilean moons are pinpoints of light.

The Moon was as sharp through this scope as any I've used. A few days past First Quarter, the crater Copernicus appeared with a hard, sharp rim. The central peak of the crater Eratosthenes was prominent with the 9mm Nagler.

When I was young, I found a copy of Garrett P. Serviss's book, *Astronomy with an Opera Glass*, at the local Carnegie library. After finishing that book, I moved on to such classics as *Pleasures of the Telescope*, also by Serviss. These books date me, but because of them, I developed a love for observing double stars, especially with small refractors. Doubles, then, would be my test, and the Tele Vue-60 did not disappoint me.

Observing

I started with Albireo (Beta [β] Cygni) — not much of a test but a real show-stopper. With the 24mm Panoptic, Albireo was easy to split. With the 9mm Nagler, Albireo stood out against a beautiful field of background stars. The Tele Vue-60's outstanding contrast was apparent with Albireo. Better contrast is an inherent advantage of refractors over most reflectors. Because of the placement of the secondary mirror in the light path of most reflectors (referred to as the central obstruction), some light is scattered into the field of view. Refractors, on the



THE THREE TELE VUE EYEPIECES used for this review were the 2.5mm Nagler, 9mm Nagler, and 24mm Panoptic. ASTRONOMY: JAMES FORBES



THE TELE VUE-60'S OPTICAL TUBE ASSEMBLY is only 11 inches long and weighs 3 pounds, but it packs a serious optical wallop. *ASTRONOMY: JAMES FORBES*



A SOFT CARRY BAG is included with the Tele Vue-60. ASTRONOMY: JAMES FORBES

2.5mm Nagler (144x). Even though atmospheric conditions were not the best, the companion of Polaris (Alpha [α] Ursae Majoris) also was visible at this magnification. With the 2.5mm Nagler, Vega (Alpha [α] Lyrae) showed a perfect Airy disk. When I moved Vega out of focus, some well-aligned diffraction rings were visible on either side of focus, attesting to the Tele Vue-60's optical quality.

The Tele Vue-60 will not disappoint observers interested in deep-sky objects either. Moving away from Albireo, I located the Dumbbell Nebula (M27) easily. Although not as bright as through larger scopes, the Dumbbell showed its distinct shape. Moving south along the Milky Way, I glimpsed the globular cluster M71 in Sagitta. Farther south, the Wild Duck Cluster (M11) in Scutum clearly stood out with its characteristic sweep of stars. Back in Lyra, the Ring Nebula (M57) was visible distinctly, looking like a perfect puff of smoke.

The wide-field views offered by the Tele Vue-60 at low power make it both a finder scope and a main observing instrument wrapped in one. While sweeping the Milky Way and other areas, an additional finder scope was never needed. The 24mm Panoptic eyepiece provides a 4.3° field of view at 15x. The high contrast offered by the optical system allowed me to see many faint objects at low power.

Details and options

The Tele Vue-60 is both compact and lightweight. Tipping the scales at 3 pounds and spanning 11 inches when closed, this scope can be slipped into a shoulder bag for easy transportation. The optical system is a 60mm apochromatic doublet with a focal length of 360mm that offers color-free images. An extendable dew cap provides hours of dew-free viewing. The dual focusing mechanism is also well thought out. A draw tube extender is coupled with a helical focuser. The entire tube assembly is tapered and easy to handle. A standard 1¼" star diagonal can be fitted into the focuser.

The Tele Vue Everbrite 1¼" mirror diagonal is undoubtedly the best choice for this scope. As good as the Tele Vue-60 is, a scope with only 2.4 inches of aperture can use all the light throughput it can get, and the Everbrite diagonal (with its higher reflectivity) provides it.

To make using the Tele Vue-60 easier, a sliding bar assembly can be used with the Tele-pod mount supplied by the manufacturer, or the sliding bar can be mounted directly onto a camera tripod. The Tele-pod mount provides a sturdy observing platform for the scope and also can be mounted on a camera tripod. Tele Vue also makes a mount specifically for use with the Tele-pod, which provides additional fine control in altitude and azimuth. A variety of other accessories are available as well.

Two eyepiece caddies can be mounted on the Tele-Pod to hold a set of eyepieces. Accessories add cost but make observing more comfortable.

The Tele Vue-60 also can be used as a "super-finder" scope. The Tele Vue-60's standard slide bar mount can be replaced with an X-Y mount system. This mount will couple to most Schmidt-Cassegrain telescopes. If you need to use mounting rings on a larger telescope, you

other hand, have no secondary and provide an unobstructed view.

I was amazed at the performance of the Tele Vue-60 when I pointed it toward Epsilon (ε) Lyrae. The famous Double-Double is a favorite object of all double-star observers. It is also an excellent test for any small refractor. As I increased the magnification, Epsilon Lyrae resolved into four distinct stars through the



TWO MIRRORED DIAGONALS are available from Tele Vue. On the right is the 60° diagonal and on the left is the more traditional 90° diagonal. The 60° unit is designed to make terrestrial viewing comfortable. ASTRONOMY: JAMES FORBES



Raymond Shubinski — a long-time fan of refractors — is the director of the East Kentucky Science Center in Prestonsburg, Kentucky.

may have some difficulty because of the Tele Vue-60's tapered body. A note of caution: You may find yourself spending more time looking through the Tele Vue-60 than through your larger scope.

As with all Tele-Vue products, the Tele Vue-60 is machined and finished exquisitely. The tube is black, anodized aluminum with brass highlighting around the helical focuser. All parts move with the precision of a fine Swiss watch. While using this scope, I tried a variety of eyepieces from other manufacturers. Tele Vue's eyepieces obviously are well-matched with this optical system and provided the best performance. I used them most often with this scope.

Many beautiful and moonless nights have passed unobserved because I was too exhausted to carry a hundred pounds of equipment into the backyard. Also, with increasing light pollution, even in rural areas, finding a dark sky becomes a major

investment in time as well as effort. With the Tele Vue-60, a set of eyepieces, a tripod, and a notebook computer, you can have a 12-pound mobile observatory that will maximize your observing time. After a long day of work, this system will set up quickly and give you hours of pleasurable observing. You even can pick the entire system up and "dodge" streetlights as you move deeper into the shadows. Of course, large-aperture telescopes are best for serious observing, but this 60mm, highly portable scope will make it easy for you to enjoy a quick evening of stargazing.

Tele Vue calls this product the "take it anywhere" telescope. It should add "anywhere, anytime" because of the easy use of the Tele Vue-60. No matter what equipment you have, the Tele Vue-60 will quickly rise to the top. After so many years of "bigger is better," it's nice to have a high-quality refractor that breaks neither the back nor the wallet. ■

/// PRODUCT SPECIFICATIONS

Tele Vue-60

2.4-inch (60mm) apochromatic refractor
360mm focal length at f/6

Uses 1¼" eyepieces

Carry bag included

Maximum true field: 4.3°

Length / Weight

11 inches / 3 pounds

Price:

\$795

Contact information:

Tele Vue Optics, Inc.

32 Elkay Drive

Chester, NY 10918

[t] 845.469.4551

[w] www.televue.com

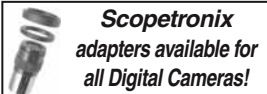


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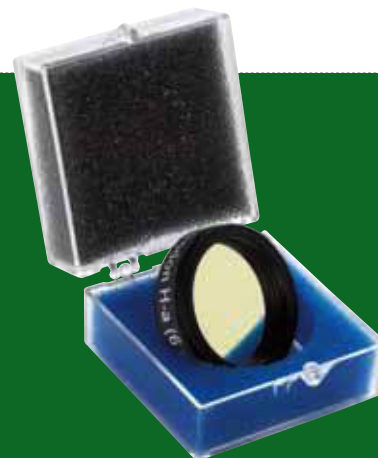




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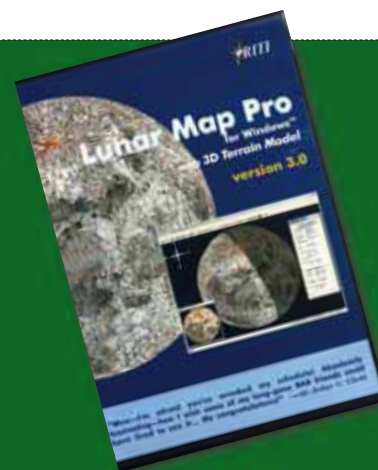
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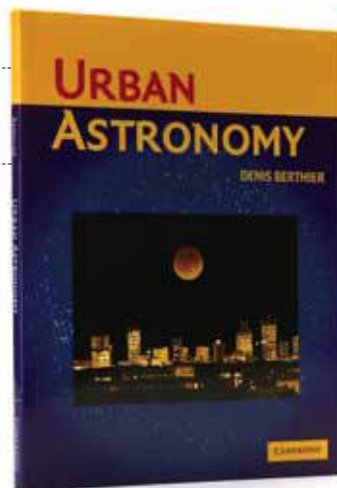
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How to enjoy the downtown sky



Urban Astronomy

Denis Berthier, 107 pages, Cambridge University Press, New York, 2004; ISBN 0-521-53190-X; paperback, \$17.99.

Thanks to technological marvels like the Hubble Space Telescope (and other orbiting observatories), plus the monster telescopes perched on remote mountaintops, everyone knows more about the universe today than at any previous time in history.

Yet most of us live in or near cities. And as they get larger and brighter, ever fewer people can experience firsthand the beauty of the stars. Living under bright lights and polluted skies makes observing more challenging for budding stargazers — and the same goes, of course, for experienced skywatchers who observe from home. But there are plenty of interesting celestial targets to hunt down even from within city limits.

Designed for those trapped within the light domes of cities, *Urban Astronomy* presents a whirlwind tour of exciting stargazing possibilities. With the entire cosmos as a backdrop, readers are quickly introduced to the essentials for enjoying the night sky in metropolitan environments. In jargon-free language, the first section explains everything from the importance of selecting an observing site away from bothersome streetlights to the life and death of stars. The author, Denis Berthier, is a journalist with 30 years of experience stargazing under the light-polluted skies of Paris. He offers both learned insights and realistic expectations for city-bound skywatchers.

Berthier uses sidebars and boxed inserts to highlight practical and useful advice intended to make observing more pleasurable. He discusses the tools of the trade and gives a basic buyer's guide for

binoculars, telescopes, and the best accessories for urban skywatching.

When it comes to what you can see, however, I spotted a drawback. Berthier's focus lies mostly on the rewards and challenges of lunar, planetary, and solar observing. That's fine, but unfortunately, his text skims over deep-sky targets, pointing out only the brightest and best-known double stars and clusters.

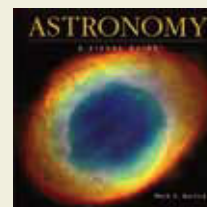
Aside from that, and despite the book being limited to only a little more than 100 pages, Berthier efficiently covers a wide spectrum of topics. He even finds room to cram in useful tables of basic astronomical events like upcoming meteor showers and eclipses.

The book's main attractions are its colorful diagrams, tables, and illustrations that range from binocular views to crisp all-sky maps with accompanying lists of highlights. Translated from French, the text in places reads a little formally for a North American audience, but this detracts little. The author has tackled his subject with up-to-date information. But it's important to remember that this book still remains only a primer for newcomers; it isn't exhaustive, nor is it intended to be.

While none of the information presented is new, this book offers an excellent introductory overview. Its best audience may be those urbanites just starting out in the hobby. This is also a good book to recommend to someone who wonders if there's *anything* celestial to see from a city.

While a trip to the dark countryside offers countless more celestial objects for the picking, *Urban Astronomy* shows that even within the confines of the city, places exist to gaze at the stars.

— ANDREW FAZEKAS is an astronomy columnist and broadcaster living in Montreal. ■



New Moon Rising

Frank Sietzen, Jr., and Keith L. Cowing, 280 pages (plus DVD), Apogee Books, Burlington, Ontario, 2004; ISBN 1-894959-12-4; hardcover, \$33.95.

The space initiative kicked off by President Bush in January 2004 sought to refocus NASA on a mission of national importance, not just buying and using rockets. This book by two experienced space journalists tells the inside story of how the new policy emerged within the White House and NASA after the Columbia disaster of February 2003. Where this bold vision will go remains to be seen, but bold it is. The DVD contains speeches by Bush, Vice President Dick Cheney, and NASA Administrator Sean O'Keefe. It also presents 13 animated sequences, some with narration and others with just "spacy" music. They depict the initiative's manned missions to the Moon, Mars, and the jovian system. The lack of an index is annoying but perhaps tolerable given the narrative's chronological structure.

Astronomy: A Visual Guide

Mark A. Garlick, 304 pages, Firefly Books, Richmond Hill, Ontario, 2004; ISBN 1-55297-958-X; hardcover, \$29.95.

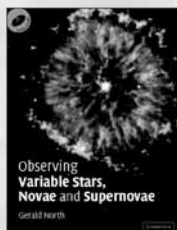
Many astronomy books tell the tale using words and images; Mark Garlick's new book puts the bulk of the effort into illustrations rather than words. The result is one of the most beautiful introductory books on astronomy in a very long time. The book would make an excellent gift for anybody keen on astronomy. If the book has a drawback, it's that the real sky you see at night simply isn't this colorful!

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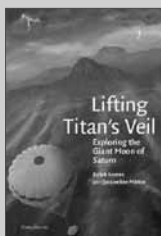
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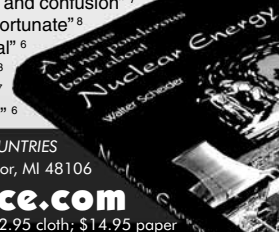
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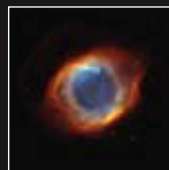
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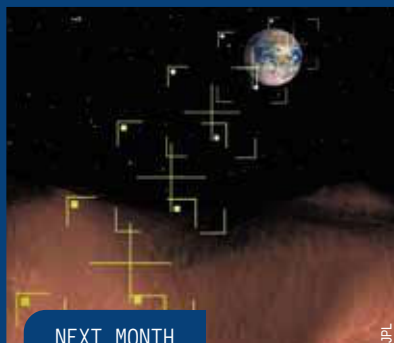
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THROUGH 11.28.04

Space: A Journey to Our Future, a traveling exhibit at the St. Louis Science Center, showcases where we've been and where we're going in space. The 12,000-square-foot exhibit, one of the largest touring space exhibits ever developed, delivers the sights and sounds of



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space exploration through live performances and interactive displays. State-of-the-art audio and visual technology provide a hands-on, educational experience for all ages.

Visitors can touch actual lunar rocks, go aboard a simulated International Space Station, pretend to take off on a Saturn V rocket, and take the helm to land a virtual lunar module.

After closing in St. Louis November 28, the exhibit will move to the Museum of Science and Industry in Tampa, Florida.

For more information on the exhibit, visit www.spaceexhibit.com.

THROUGH FEBRUARY 2005

Astro Images of New Mexico

LodeStar Astronomy Center, Albuquerque, New Mexico. Cosponsored by LodeStar and the Albuquerque Astronomical Society, this year's display includes categories in film, digital, and plate formats. For more information, contact Karen

Keese at 505.841.5972; e-mail, pr@taas.org; web sites, www.taas.org and www.lodestar.unm.edu.

10.27.04–10.28.04

SLOOH's Worldwide Lunar Eclipse Star Party

On-line event. From 0h00m UT until 5h00m UT, the SLOOH telescopes will observe the total lunar eclipse. During the coverage, SLOOH will run several Moon observing missions per hour, intermixed with deep-sky missions. *Astronomy* magazine readers will be able to view all group missions during the coverage period. For more information, visit www.slooh.com.

11.02.04–11.04.04

Workshop on Advanced Space Technologies for Robotics and Automation

European Space Research and Technology Center, Noordwijk, Netherlands. Sponsored by the European Space Agency, this

international symposium provides a forum for scientists and engineers to discuss developments in automation and robotics in space missions. For more information, visit www.congrex.nl/04c21.

11.06.04

North Texas Skywatch Star Party

Lake Mineral Wells State Park, Mineral Wells, Texas. This family-friendly star party is hosted by Tarleton State University and Tarrant County College. Attendees are encouraged to bring their scopes to share views with beginners who have never looked through an eyepiece. For more information, visit www.tarleton.edu/~planetarium.

11.07.04–11.14.04

Chiefland Star Party

Chiefland Astronomy Village, Chiefland, Florida. This laid-back star party provides nonmembers a chance to view and participate in the great activities members of the Chiefland community enjoy year-round. For more information, visit www.c-av.com.

11.14.04

Astrofestival

University of Oslo, Oslo, Norway. This sixth annual event features an enormous solar system model, an exhibition of Don Dixon's art, and the chance to build a spaceship sponsored by LEGO. For more information, e-mail Michael Baziljevich at michaelb@fys.uio.no; web site, www.astrofestival.no/english.php.

11.22.04–12.03.04

Canary Islands Winter School of Astrophysics

Cabildo Insular de Tenerife Conference Center, Puerto de la Cruz, Canary Islands, Spain. The theme for this year's event is "Extrasolar Planets." For more information, visit www.iac.es/winters.

12.13.04–12.17.04

American Geophysical Union Fall Meeting

San Francisco. This meeting provides an

occasion for researchers, teachers, and students to discuss the latest issues affecting Earth, the planets, and their environments in space. Lectures will cover all areas of geophysical science. For more information, call 800.966.2481, ext. 333; e-mail, meetinginfo@agu.org; web site, www.agu.org.

01.09.05–01.13.05

American Astronomical Society Meeting

San Diego. This gathering will feature lectures, workshops, and special events. *Astronomy* senior editor Robert Burnham will attend this meeting. For more information, e-mail aas@aas.org, web site, www.aas.org.

02.07.05–02.12.05

Winter Star Party

Camp Wesumkee, West Summerland Key, Florida. Sponsored by the Southern Cross Astronomical Society, the Winter Star Party celebrates its 21st annual gathering. Twelve-hour observing sessions at this dark-sky site will provide ample time to target celestial beauties. *Astronomy* assistant editor Matt Quandt will attend the star party. For more information, visit www.scas.org.

02.17.05–02.21.05

American Association for the Advancement of Science Annual Meeting

Washington, D.C. The theme of this year's gathering is "The Nexus: Where Science Meets Society." Besides astronomy, the meeting will cover all other disciplines of science. *Astronomy* assistant editor Pamela Zerbinos will attend this meeting. For more information, visit www.aaas.org/meetings. ■

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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RESOURCES

Learn more about this issue's topics:

THE AMAZING LIVES OF TWO STARS

BOOKS — Ray Jayawardhana's *Star Factories: The Birth of Stars and Planets* (Rain-tree Steck-Vaughn, Austin, Texas, 2001) offers myriad colorful illustrations and easy-to-follow descriptions of the star-formation process.

James Kaler's *Stars* (Scientific American Library, New York, 1992) provides a comprehensive overview of its title subject. Organized like a textbook, *Stars* offers an array of images and diagrams. More advanced readers should pick up *Advances in Stellar Evolution*, edited by R. T. Rood and A. Renzini, (Cambridge University Press, New York, 1997) to learn about progress in this area of research.

ARTICLES — Alex Filippenko discusses the life of a star after its stint as a white dwarf in "When stars explode" (*Astronomy*, February 2003). Paul Hodge's "Spying the neighbors" (*Astronomy*, March 2002) takes a close look at the Magellanic Clouds and explains their relevance to star formation.

WEB — To read about Cecilia Payne-Gaposchkin and her historic contributions to astronomy, visit www.harvardsquarelibrary.org/unitarians/payne2.html.

RED SUN DYING

BOOKS — *Nearest Star: The Surprising Science of our Sun* by solar astrophysicists Leon Golub and Jay M. Pasachoff (Harvard University Press, Cambridge, Massachusetts, 2001) is an engaging and well-written account of what we do and do not know about the Sun.

For one look at how the Sun might influence our home planet, check out *The Life and Death of Planet Earth* by Peter D. Ward and Donald Brownlee (Times Books, New York, 2002).

WEB — Find information on the Sun at sohowww.nascom.nasa.gov, the site of the Solar and Heliospheric Observatory (SOHO). Keep track of the search for exoplanets with the extrasolar planet encyclopedia at cfa-www.harvard.edu/planets.

THE LOOMING DEATH OF HUBBLE

BOOKS — *The Space Telescope* by Robert W. Smith (Cambridge University Press, New York, 1989) documents the great undertaking to get Hubble built.

Reading *The Hubble Wars* by Eric Chaisson (Harper Collins, New York, 1994) is a fascinating experience today, when we tend to forget the arguments that arose when the telescope was being planned and launched.

WEB — The main site for HST information and documents is www.stsci.edu/hst.

ASK ASTRO

BOOK — James Kaler's *Extreme Stars* (Cambridge University Press, New York, 2001) discusses Wolf-Rayet (WR) stars.

ARTICLE — For more on WR stars and the supernova connection, see Francis Reddy's "The star-splitting jets of supernovae" (*Astronomy*, October 2004).

WEB — James Kaler's "Stars" web site, www.astro.uiuc.edu/~kaler/sow/sow.html, features a discussion on Gamma (γ) Velorum. For positions, brightnesses, and other information on WR stars in the Milky Way, see K. A. van der Hucht's "Seventh Catalogue of Galactic Wolf-Rayet Stars," published in 2001 and available on-line through the VizieR Catalogue Service at vizier.u-strasbg.fr.

RAMBLING IN THE LUNAR ALPS

BOOKS — A good guidebook to exploring the Moon by telescope is Charles Wood's *The Modern Moon* (Sky Publishing, Cambridge, Massachusetts, 2003).

For observing, the best lunar atlas is Antonín Růkl's *Atlas of the Moon* (Kalmbach Publishing Co., Waukesha, Wisconsin, 1992). This atlas is out of print, but you may find used copies for sale.

Finally, no Moon-buff should miss Don Wilhelms's insider account of lunar science from the 1950s through the 1970s: *To a Rocky Moon* (University of Arizona Press, Tucson, 1993).

WEB — A well-organized page on lunar atlases (photographic and cartographic) is hosted by the Lunar and Planetary Institute at www.lpi.usra.edu/research/lunar_atlases. The most thorough account of lunar geology is Don Wilhelms's *The Geologic History of the Moon* (U.S. Geological Survey, Denver, 1987), but it is long out of print. An on-line version is available, however, (as downloadable PDF files) at cps.earth.northwestern.edu/GHM.

THE BACKYARD TELESCOPE

BOOKS — For a general history of telescopes and their makers until the 1950s, see Henry C. King's *The History of the Telescope* (Dover Publications, Mineola, New York, 2003). In the heavily illustrated *Astronomy Through the Telescope* (Van Nostrand Reinhold, New York, 1981), Richard Learner tells the history of astronomy (up to the early 1980s) through the development of the telescope.

If you're shopping for a telescope for yourself, check out *The Backyard Astronomer's Guide* by Terence Dickinson and Alan Dyer (Firefly Books, Buffalo, New York, 2002). More than any other guide to backyard observing, this excellent book focuses on equipment.

WEB — The Stellafane convention's site at www.stellafane.com lets you explore the old days of telescope-making and the hobby's modern descendants. Old-time telescope-maker John Brashear has a page devoted to him at johnbrashear.tripod.com.

The Antique Telescope Society is dedicated to collecting and using telescopes; check it out at www1.tecs.com/oldscope.

CLASSROOM ASTRONOMY

WEB — To set up your own Project ASTRO site, to learn about the regional sites, or to gather Project ASTRO resource material, visit www.astrosociety.org/education/astro/project_astro.html. For more information about Family ASTRO, visit www.astrosociety.org/education/family.html. ■

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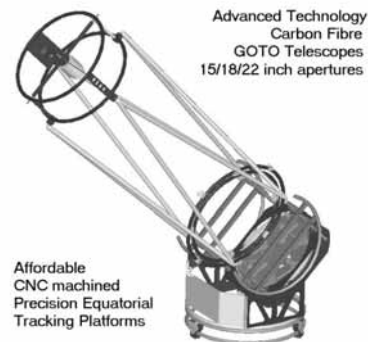
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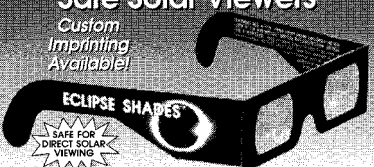
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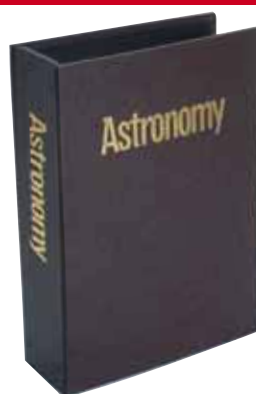
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THE RING NEBULA (M57) (14.5-inch Astrographic Cassegrain reflector at f/8, SBIG ST-10E CCD camera, hydrogen-alpha/LRGB image with a 2-hour luminance exposure for the background, a 45-minute luminance exposure for the Ring, a 3-hour exposure through a H α filter, 1-hour exposures each for the background in R, G, and B, and 30-minute exposures each for the Ring in R, G, and B)

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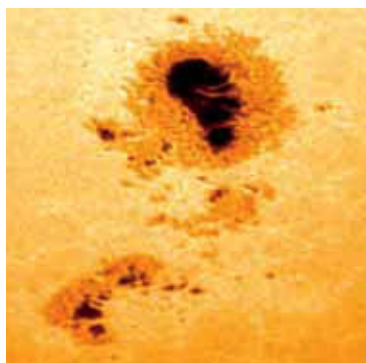
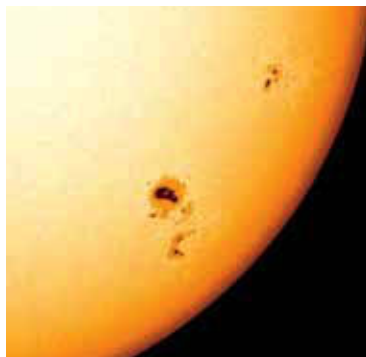
Top, THE RUNNING CHICKEN NEBULA (IC 2948)
(4-inch Pentax SDP refractor at f/6.4, Starlight X-Press SXV-H9 CCD camera, H α /LRGB image with exposure times of 2,700, 1,200, 700, 700, and 700 seconds, respectively) /// GERALD RHEMANN AND MICHAEL JÄGER

Bottom, SATURN OCCULTS THE STAR SAO 78867
(9-inch Astro-Physics apochromatic refractor at f/15, Philips ToUcam Pro, each image is a stack of between 700 and 1,000 frames, taken from 6h26m UT to 7h56m UT, November 15, 2003, from Charleston, South Carolina) /// JIM PHILLIPS

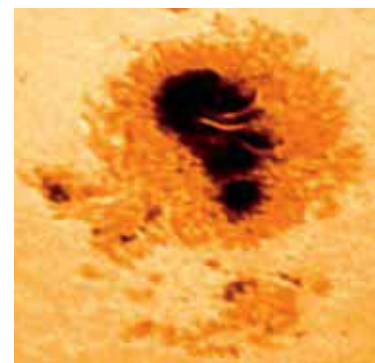
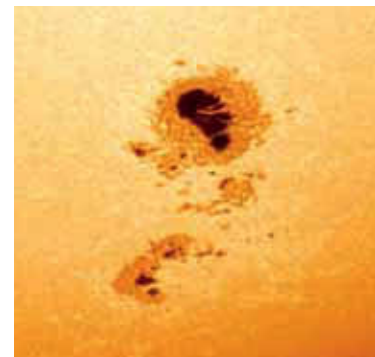
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Bottom left, WIDE-FIELD VIEW OF THE TRIFID NEBULA (M20) (4-inch Takahashi FSQ-106 apochromatic refractor, SBIG ST-10XME CCD camera, Astrodon Tru-Balance color filters, H α /RGB image with exposure times of 60, 45, 45, and 45 minutes, respectively) /// DON GOLDMAN



Top, SPIRAL GALAXY NGC 2903 IN LEO (14.5-inch Astrographic Cassegrain reflector at f/8, SBIG ST-10E CCD camera, Astrodon Tru-Balance color filters, LRGB image with exposures of 240, 105, 105, and 105 minutes, respectively) /// TONY AND DAPHNE HALLAS



Bottom right, SUNSPOT GROUP AT FOUR FOCAL RATIOS (3.2-inch Vixen fluorite apochromatic refractor at f/8, f/18, f/29, and f/45; Philips ToUcam Pro, Baader ND5 solar film, between 60 and 120 frames of $\frac{1}{25}$ -second exposures; taken July 19, 2004, from 6h47m UT to 7h03m UT) /// DAMIAN PEACH



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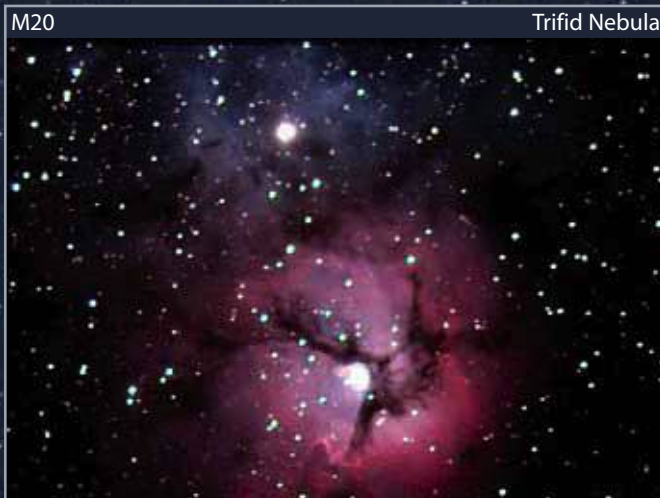
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